THE EFFECT OF A SIX-WEEK WHOLE BODY VIBRATION TRAINING PROTOCOL ON THE PHYSICAL CAPACITIES AND FATIGABILITY OF OVERWEIGHT YOUNG FEMALE ADULTS

By

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Abstract

Whole body vibration (WBV) training is a relatively new training technique and is considered low intensity as it elicits non-voluntary muscle contractions generated by mechanical vibrations. The aim of this study was to examine the effects of a 6-week WBV training paradigm on the physical capacities and fatigability of overweight young female adults. We hypothesized that WBV would increase fat free mass as well as leg power and strength, decrease the fatigue index of the lower limbs during the Wingate test, increase fatigue resistance, improve neuromuscular efficiency and decrease fatigue perception in overweight young female adults.

Participants (n=24) were overweight young female adults (body fat percentage 30-35) between the ages of 20 and 40 and were randomized into 2 groups; control group (CON; n=10) or whole body vibration group (VIB; n=14). This study consisted of six weeks of training and four testing sessions: 2 before (sessions 1 & 2) and 2 following (sessions 3 & 4) the training regimen. During testing sessions 1 and 3, the basal metabolic rate, body composition, leg power (Wingate), elasticity index (EI), squat and countermovement jumps and fatigue perception (questionnaires) were assessed for all subjects. Isokinetic tests to measure strength and muscle fatigue tests were performed during testing sessions 2 and 4. The training protocol lasted 6 weeks and exercises were performed 3 times a week. Sessions lasted 30 minutes and entailed 15 sets of 1-minute exercises followed by 1-minute rest intervals. One set consisted of 15 controlled and timed squats (15 flexion and extension per minute). The VIB group performed their exercises on the power Plate® pro 6. Vertical vibration amplitude settings were kept on low (2mm) throughout the entire 6 weeks and set at a frequency of 30Hz for weeks 1-3 and increased to 35Hz for weeks 4-6. The CON group performed the same exercises without vibration.

The results revealed that a 6-week WBV training regimen had no effect on body composition or basal metabolic rate. WBV training did not affect EI as evidenced by similar squat jump and countermovement jump measures for both the CON and VIB groups. WBV training had no effect on leg power as measured using the Wingate ergocycle. The Wingate test did show a decrease in the fatigue index for both groups ($p<0.05$). Unexpectedly, a decrease in strength was found in extension phase during the eccentric contractions (120°/s) and flexion phase during concentric contractions (120°/s and 180°/s). As there were no changes in fat free mass, it seems that the reduction in strength was due to central changes. The fatigue rate represented by regression slopes showed that the VIB group was more fatigue resistant post training compared to the CON group. Fatigue perception as measured using a multidimensional approach with questionnaires (FSS, MFI and SHARP) revealed no changes in fatigability for either group.

To conclude, this study demonstrated that WBV training in overweight young female adults had minimal effects on the physical capacities and fatigability of our subjects. Higher intensity vibration parameters, a longer training regimen or individualized vibration parameters may have greater benefits for overweight subjects and should be considered in future studies.

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Liste des abréviations

BF; Biceps Femoris

BMI; Body mass index

BMR; Basal metabolic rate

CMJ; Countermovement jump

CON; Control group

Con; Concentric

Ecc; Eccentric

EI; Elasticity index

EMG; Electromyography / électromyogramme

FFM; Fat free mass

FI; Fatigue index

HH; High-frequency and high peak-to-peak displacement group

HW; Hydrostatic weighing

IMC; Indice de masse corporelle

Iso; Isometric

LL; Low-frequency and low peak-to-peak displacement group

MB: Métabolisme de base

NME; Neuromuscular efficiency

PV; sur plateforme de vibration

RF; Rectus Femoris

RMS; Root mean square

RTV; Réflexe tonique vibratoire

SD; Standard deviation

SJ; Squat jump

SSC; stretch shortening cycle / cycle étirement détente

VIB; Whole body vibration group

VL; Vastus Lateralis

VM; Vastus Medialis

WBV; Whole body vibration

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CHAPITRE 1 : REVUE DE LITTÉRATURE

1.1 Introduction

L'activité physique, qu'elle soit sous forme aérobie ou anaérobie intrigue une multitude de professionnels de différentes disciplines, notamment dans le contexte de la rééducation et celui du sportif. De nos jours, il est presque inévitable de remarquer ces plateformes de vibration « Whole body vibration (WBV) » qui grimpent en popularité dans nos salles d'entraînement. L'incorporation de ces appareils est actuellement testée entre autres, dans le domaine du sport, de la gérontologie et de la réhabilitation (C. Bosco, Colli, et al., 1999; Rittweger, 2010; Rittweger, Just, Kautzsch, Reeg, & Felsenberg, 2002). L'entraînement sur plateforme à vibration (PV) consiste à exposer le corps entier à des vibrations mécaniques en se mettant sur une plateforme vibrante et en appliquant des exercices statiques ou dynamiques. Ces vibrations sont caractérisées par la fréquence (mesurée en Hertz), l'amplitude (mesurée en mm), la direction (verticale ou sinusoïdale), la magnitude (1g = 9.81 m/s^2) et la durée de l'exposition (minutes) (Totosy de Zepetnek, Giangregorio, & Craven, 2009). Au fil des années, les effets aigus ainsi que les effets chroniques d'un entraînement en vibration sur les adaptations neuromusculaires ont été documentés par plusieurs équipes de chercheurs (A. C. Bogaerts et al., 2009; C. Bosco, Cardinale, & Tsarpela, 1999; Cardinale & Wakeling, 2005; Dabbs, Munoz, Tran, Brown, & Bottaro, 2011; Rittweger, 2010).

Les plateformes vibrantes ont été développées par des ingénieurs biomécaniques d'Europe pour prévenir le changement de la densité osseuse des astronautes. Ce n'est qu'en 1985 que Nazarov et Spivak utilisent la vibration comme modalité d'exercice pour les athlètes. Les effets d'entraînement PV ont été le sujet de plusieurs études récentes. Les articles publiés qui examinent les effets chroniques et aigus montrent plusieurs variations quant aux paramètres des protocoles employés. Premièrement, l'intervalle des fréquences de vibrations s'étend de 25-50Hz. Deuxièmement, la période d'exposition aux vibrations par séance varie de 30 secondes à

20 minutes. Troisièmement, la direction de vibration varie selon l'appareil utilisé; vibrations verticales et vibrations sinusoïdales. Quatrièmement, l'amplitude de la vibration utilisée varie de 2 mm à 10 mm. Enfin, la magnitude des vibrations peut varier de 1 g à 5.5g (Merriman & Jackson, 2009). Des différences existent aussi en ce qui concerne les sujets testés; plusieurs études portent sur les sujets sains et jeunes athlètes et d'autres, sur les sujets âgés (Cardinale & Pope, 2003). Même si la plupart des études font usage d'un groupe dit contrôle, on y retrouve de très grandes différences. Certains groupes contrôles sont dit passifs et d'autres actifs. Les groupes passifs ne font rien alors que les groupes actifs accomplissent le même entraînement que le groupe expérimental, mais sans vibration. Il est bel et bien clair que comparer les résultats de ces études doit être fait avec de grandes précautions, puisque des conclusions erronées peuvent y être déduites.

Cette revue de littérature vise à instruire le lecteur au sujet des effets des plateformes de vibrations comme modalité d'entraînement. Les paramètres de la vibration seront décrits, suivis des réactions et mécanismes du corps humain face aux vibrations. Le cœur de cette revue de littérature discutera des adaptations neuromusculaires, des effets aigus et chroniques dus aux entraînements PV. Finalement, les objectifs du projet de recherche seront résumés.

1.2 Les vibrations : le fondamental

Qu'est-ce qu'une vibration ? Une vibration est définie comme un mouvement oscillatoire autour d'un point de référence stable (Nordlund & Thorstensson, 2007). Les caractéristiques de vibrations sont documentées pour mieux comprendre leurs effets ergogéniques. Ces caractéristiques, mentionnées plus haut, sont : la direction, la fréquence, l'amplitude, la durée d'exposition ainsi que la magnitude. Plusieurs types de plateformes vibrantes sont disponibles sur le marché. Ces plateformes peuvent être différentes en ce qui concerne le type de vibration, la fréquence, l’amplitude et l’accélération.

En ce qui concerne les plateformes à vibration, il existe deux différents types de vibrations pouvant être émis par ces appareils (figure 1.1); les vibrations verticales et les vibrations sinusoïdales. Les plateformes aux vibrations dites verticales (exemple : Power Plate®), transmettent un stimulus vertical et synchronisé sur toute la plateforme qui cause un mouvement simultané des membres inférieurs. À l’opposé, les plateformes aux vibrations sinusoïdales, aussi dites vibrations oscillatoires (exemple : plateforme Galileo 2000) ne fonctionnent pas de la même manière (figure 1.1). Celles-ci s’inclinent d’un côté et de l’autre sur un point d’appui au centre de la plateforme, de telle sorte que plus les pieds sont séparés, plus l’amplitude augmente. Comparée à la plateforme verticale, la plateforme sinusoïdale cause un mouvement asynchrone aux pieds et aux membres inférieurs (Abercromby et al., 2007b; Cardinale & Wakeling, 2005; Merriman & Jackson, 2009; Rittweger, 2010; Totosy de Zepetnek et al., 2009). Moins d’énergie est transférée à la colonne vertébrale ainsi qu’à la tête avec les plateformes sinusoïdales comparées aux plateformes verticales. Ceci peut être bénéfique pour les populations vulnérables comme les sujets âgés. Cependant, la nature asynchrone de ces plateformes peut rendre l’exercice très difficile pour ces populations car il faut pouvoir garder son équilibre alors que la nature synchronisée des plateformes verticales peut faciliter l’exercice chez les sujets âgés (Merriman & Jackson, 2009).

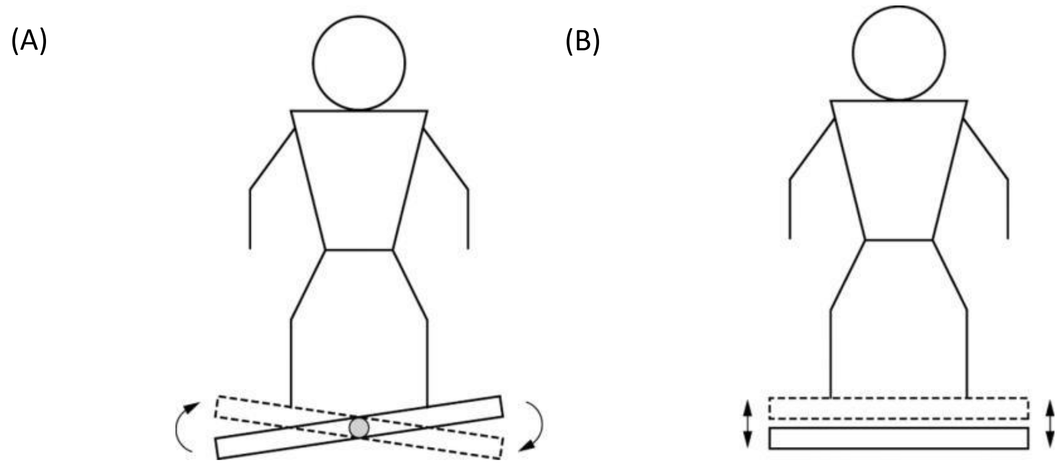

Figure1.1 : Comparaison des types de vibrations; vibrations sinusoïdales (A) et vibrations verticales (B) (Woggon, 2012)

L'intensité d'un exercice PV est déterminée par la fréquence et l'amplitude des vibrations. La fréquence est définie comme le taux de répétitions des cycles de vibration en une seconde, mesurée en Hertz (A. C. Bogaerts et al., 2009; Cardinale & Wakeling, 2005; Rittweger, 2010; Totosy de Zepetnek et al., 2009). L'amplitude est l'ampleur d'oscillation de la vibration, mesurée en millimètres (A. C. Bogaerts et al., 2009; Cardinale & Wakeling, 2005; Rittweger, 2010; Totosy de Zepetnek et al., 2009). La magnitude de la vibration est indiquée par l'accélération, qui est mesurée en g, où 1 g = 9.81 m/s^2 et dépend de l'intensité de la vibration, c'est-à-dire de la fréquence et de l'amplitude. L'équation est la suivante : $A = 2 * \pi^2 * F^2 * D$; A est l'accélération (m/s^2), D est l'amplitude (en mm) et F est la fréquence (en Hertz) (Totosy de Zepetnek et al., 2009). Les paramètres choisis pour la fréquence et l'amplitude des vibrations d'un entraînement peuvent avoir des répercussions sur les résultats. Il est donc important de comprendre les réactions du corps face aux vibrations.

1.3 Le résonateur : le corps et les vibrations

1.3.1 Les structures importantes

Un corps rigide exposé à des vibrations suit la trajectoire oscillatoire du transducteur. Le corps humain quant à lui n'est pas un corps rigide. Plusieurs structures telles que les muscles, les tendons, les cavités synoviales et les os jouent un rôle crucial d'amortisseur lorsque le corps est exposé aux vibrations (Cardinale & Pope, 2003). Avant de pouvoir expliquer comment le corps se protège des vibrations, il faut avant tout comprendre les caractéristiques des structures du corps.

Toutes les structures du corps ont une résonance naturelle, c'est-à-dire une fréquence et amplitude auxquelles elles vibrent naturellement. Celle-ci est déterminée par la masse et la tonicité de cette structure. Les organes du corps vibrent à des fréquences qui varient entre 5 et 20 Hz. Par exemple, la résonance naturelle du triceps sural, des quadriceps et du tibial antérieur est d'à peu près 10Hz (Wakeling & Nigg, 2001). Quand la fréquence de la vibration à laquelle est exposé le corps approche la fréquence naturelle d'une structure, une augmentation de l'amplitude de vibration de cette structure se produit, ce qui peut être dangereux. Lorsque cela se produit, pour se protéger, la structure peut changer de tonicité pour éviter les effets néfastes de cette amplification. Par exemples, la tonicité musculaire est modifiée en engageant la contraction musculaire (Abercromby et al., 2007). En d'autres mots, la transmissibilité des vibrations peut être diminuée en augmentant l'activité musculaire.

1.3.2 La transmissibilité

La transmissibilité se fait de membre à membre ; des pieds aux mollets, des mollets aux cuisses, etc. Cette transmissibilité peut être atténuée par plusieurs facteurs tels que la posture, la rigidité des muscles, le positionnement des pieds et la fréquence de la vibration émise. Les muscles de la cuisse et des mollets sont vus comme amortisseurs principaux en ce qui concerne les vibrations appliquées aux pieds (Cochrane, Stannard, Walmsely, & Firth, 2008). En se tenant sur la pointe des pieds, la cuisse et le mollet peuvent agir comme amortisseur avant que les vibrations ne se déplacent au tronc. La flexion des genoux augmente l'absorption d'énergie des muscles de la cuisse, ce qui diminue la transmissibilité des vibrations au tronc, au dos, à la tête et aux yeux (Cardinale & Pope, 2003).

1.4 Les mécanismes neuromusculaires

L'amélioration post entraînement, qu'elle soit avec ou sans vibration est non seulement attribuée aux mécanismes périphériques comme l'hypertrophie musculaire, mais aussi aux mécanismes centraux. Les changements neuraux (ex. recrutement des unités motrices) sont les premiers mécanismes d'adaptation du muscle à l'entraînement. En effet, une augmentation de force musculaire peut être observée en absence d'hypertrophie musculaire. Effectivement, les changements morphologiques musculaires peuvent prendre de plusieurs mois à une année pour se manifester (Rittweger, 2010).

Les mécanismes d'adaptations à l'entraînement PV ne sont pas encore très bien connus. Plusieurs théories neuromusculaires et métaboliques ont été mises en l'avant, mais peu ont été testées.

L'application de vibrations sur le muscle entraîne une réponse neuromusculaire connue sous le nom de réflexe tonique vibratoire (Mahieu et al., 2006). Les vibrations causent des changements de longueurs du muscle qui sont captés par le fuseau neuromusculaire (Nakajima, Izumizaki, Sekihara, Atsumi, & Homma, 2009). Ce dernier est un mécanorécepteur sensible aux changements de longueur du muscle. Lorsque celui-ci est activé, il envoie un signal par les fibres primaires (Ia afférentes) puis une activation du muscle est produite par les motoneurones alpha pour que le muscle revienne à sa longueur initiale (contraction musculaire).

1.5 Les effets aigus d'un entraînement PV

Plusieurs recherches se sont concentrées sur les effets aigus physiologiques, métaboliques et neuromusculaires de l'entraînement PV (Adams et al., 2009; Zamparo, Perini, Orizio, Sacher, & Ferretti, 1992). Ces études ont cherché à justifier l'utilisation de l'entraînement PV pour l'amélioration de la performance. Les résultats de ces études quant à l'efficacité de ces appareils sont loin d'être uniformes. Il faut souligner la variabilité des paramètres de vibration, du protocole et même du type de participants (tableau 1.1).

Tableau 1.1. Études d'entraînement avec plateformes de vibration.

Étude	Sujets (N)	Âge moyen (années)	F (Hz)	A (mm)	Durée (semaines)	Sessions	Séries	Résultats
Delecluse et al. (2003)	18 femmes sédentaires	21.4	35-40	1.25-2.5	12	3x/semaine	------	↑ de la force des extenseurs du genou +17%
Verschueren et al. (2004)	70 femmes post-ménopause	64.3	35-40	------	24	3x/semaine	------	↓ de % de la masse grasse ↑ de la force des muscles extenseurs du genou en isométrie et en dynamique
Bautmans et al. (2005)	24 hommes âgés	77.5	30-40	------	6	3x/semaine	4x30-60s	Aucun changement
Bogaerts et al. (2007)	25 hommes sédentaires	67.3	35-40	1.25-2.5	52	3x/semaine	4x30s 11x60s	↑ de la force en isométrie des extenseurs du genou +10% ↑ du saut en hauteur +11%
Roelants et al. (2004)	18 femmes actives	21.3	35-40	1.25-2.5	24	3x/semaine	------	↑ de la masse maigre +2.2% ↑ de la force en isométrie des extenseurs du genou +24%
(Milanese et al. (2013)	50 femmes obèses	46.8	40-60	2-5	10	2x/semaine	14 min	↓ de l'IMC et masse grasse ↑ de force des membres inférieurs

F : fréquence; A : amplitude.

1.5.1 Adaptations métaboliques

L'évaluation de la consommation d'oxygène et du métabolisme énergétique pendant l'entraînement PV est un sujet d'étude récent. Ce que l'on se demande, c'est si la vibration peut causer une plus grande réponse cardiovasculaire qu'un exercice traditionnel tel que la course sur tapis roulant ou l'entraînement sur ergocycle. Ces résultats pourraient avoir d'énormes implications pour les populations spéciales comme les sujets âgés, les personnes obèses et les gens souffrant de maladies cardiovasculaires.

Rittweger et al. (2000) ont montré que l'exercice PV jusqu'à l'épuisement induit une réponse cardiovasculaire faible chez les sujets sains (50% du VO_2max). Même si l'entraînement PV n'augmente pas significativement la consommation d'oxygène, une augmentation de VO_2 de 4,5 ml $0_2 \bullet kg^{-1} \bullet min^{-1}$ mesurée sur les plateformes a été observée en comparant au groupe contrôle (à 26Hz) (Rittweger, Beller, & Felsenberg, 2000). Une autre étude chez les sujets sains a démontré qu'un métabolisme requis pour un exercice PV à une fréquence de 26Hz et une amplitude de 6mm est comparable au métabolisme nécessaire pour une marche à intensité modérée (Zamparo et al., 1992). En outre, on retrouve une relation linéaire entre le VO_2 et la fréquence et l'amplitude de la vibration (Cochrane, Sartor, et al., 2008; Rittweger, Ehrig, et al., 2002). Finalement, plusieurs études sur les entraînements PV démontrent que celles-ci augmentent le métabolisme énergétique d'environ 1 MET, soit 3.5 ml $0_2 \bullet kg^{-1} \bullet min^{-1}$ (Cochrane, Sartor, et al., 2008; Rittweger, Beller, & Felsenberg, 2000; Rittweger, Ehrig, et al., 2002; Rittweger, Schiessl, & Felsenberg, 2001). Les effets des exercices de type PV sur la réponse cardiovasculaire sont donc limités.

Une augmentation du lactate sanguin durant un exercice indique non seulement un exercice de haute intensité, mais le recrutement du métabolisme anaérobie. Cette augmentation est souvent trouvée durant les exercices de haute intensité, mais de courte durée. Quelques études ont investigué l'effet de l'exercice PV sur le lactate et ont constaté seulement une faible augmentation non significative (Goto & Takamatsu, 2005). Rittweger et al. (2000) ont comparé un exercice sur bicyclette aux exercices PV (tous deux jusqu'à l'épuisement) ; la moyenne du lactate sanguin était de 7.7mmol.L^{-1} et 3.95mmol.L^{-1} respectivement (Rittweger et al., 2000). Ces résultats suggèrent que l'entraînement PV n'est pas efficace pour solliciter le système anaérobie.

1.5.2 Adaptations neuromusculaires aigues

Comme mentionné plus haut, l'application de vibration sur un muscle cause une réponse neuromusculaire connue sous le nom de réflexe tonique vibratoire (RTV) (Mahieu et al., 2006). Grâce au RTV, il y a une amélioration de la contraction musculaire car celle-ci cause une augmentation d'activation d'unités motrices et une suppression de l'inhibition de la contraction musculaire via les organes tendineux de Golgi (Adams et al., 2009). Quelques questions se posent : Est-ce que l'entraînement PV affecte la force et la puissance musculaire ? Est-ce que les vibrations augmentent la fatigue ou modifient le type de fatigue (périphérique vs centrale) ? Le système neuroendocrinien a-t-il un rôle à jouer ?

Selon la théorie du RTV, les fuseaux neuromusculaires envoient des signaux à la moelle épinière, ce qui active un réflexe causant une contraction musculaire soutenue. La potentialisation par post-activation est l'échauffement qui précède un entraînement qui a comme but d'augmenter la force ou la puissance musculaire (Lorenz, 2011). Bosco et al. (1999) ont été les premiers à étudier les effets aigus de l'entraînement PV sur la puissance musculaire. Leurs sessions sur les joueurs élites de volleyball consistaient en 10 périodes de 60 secondes de PV à une fréquence de 26Hz et une amplitude de 10mm. Ils ont observé une augmentation de puissance sur le « leg press » de 6 - 8% ainsi qu'une augmentation de la détente après 10 minutes de PV (C. Bosco, Colli, et al., 1999). Des résultats similaires ont été retrouvés pour la détente chez les joueuses de hockey sur gazon (Cochrane & Stannard, 2005). L'entraînement PV semble avoir des effets aigus positifs et c'est pour cela, qu'il est souvent utilisé comme échauffement. Une étude a comparé différents échauffements (passif, sur bicyclette, squats dynamiques avec et sans vibration) et a montré qu'un échauffement PV serait plus efficace que les échauffements traditionnels pour les sports dont la puissance est cruciale (Cochrane, Stannard, et al., 2008).

Lorsque la sollicitation de l'entraînement PV est plus longue, des phénomènes de fatigue peuvent se produire. Plusieurs études se sont intéressées aux effets de longues sessions d'entraînement PV sur la fatigue. La majorité d'entre elles ont démontré une baisse de la force isométrique suivant une session de PV (de Ruiter, Van Raak, Schilperoort, Hollander, & de Haan, 2003; Erskine, Smillie, Leiper, Ball, & Cardinale, 2007). Rittweger et al. (2000) ont trouvé une réduction du saut contre-mouvement (CMJ) ainsi qu'en faisant une contraction maximale volontaire après un entraînement PV. Moins de force était produite avec une diminution de fréquence médiane d'EMG.(Rittweger et al., 2000). Il semble que la littérature présente des résultats unanimes, que la force musculaire diminue après une longue session de PV. À partir de cela, il est possible de penser que le système nerveux central pourrait contribuer en partie à la fatigue pendant les entraînements PV. Les prochaines études devraient bien décortiquer la fatigue neurale et périphérique après un entraînement PV pour pouvoir mieux comprendre comment celui-ci affecte la fatigue musculaire, la puissance musculaire et la force musculaire.

1.5.3 Adaptations endocriniennes

Les mécanismes à la base des effets aigus sur le système musculaire de l'entraînement PV ne sont toujours pas connus. Lors d'un exercice traditionnel des signaux de régulation sont envoyés par le système hormonal. Ces réponses endocrines ont été documentées pendant longtemps et elles incluent entre autres des changements dans les niveaux de l'hormone de croissance, de la testostérone et de l'insuline.

Lors d'exercices contre résistance intenses, on retrouve une augmentation de testostérone. Bosco et al. (2000) ont été les premiers à retrouver cette même augmentation de testostérone en réponse à l'entraînement PV (C. Bosco et al., 2000) mais d'autres études subséquentes n'ont pas observé d'augmentations (Cardinale, Leiper, Erskine, Milroy, & Bell, 2006; Erskine et al., 2007). Une étude a pu démontrer une élévation de testostérone plasmatique durant un exercice traditionnel avec et sans vibration alors qu'aucun effet n'a été retrouvé avec seulement une application de vibration. Cette étude suggère que, seule, la vibration n'affecte pas la sécrétion de testostérone (Kvorning, Bagger, Caserotti, & Madsen, 2006). Bosco et al. (2000) ont trouvé une augmentation du taux d'hormone de croissance associé à l'entraînement PV mais ce résultat n'a pas été rapporté par d'autres (Cardinale & Rittweger, 2006; Goto & Takamatsu, 2005). Le jeûne, l'exercice et le sommeil peuvent tous favoriser la sécrétion d'hormone de croissance mais celle-ci peut être inhibée entre autre par l'hyperglycémie et par une forte concentration existante d'hormone de croissance. Il est important de noter que cette hormone est relâchée pulsativement et que sa détection peut souvent être difficile (Goto & Takamatsu, 2005). Pour la glycémie et les hormones impliqués, une étude comparant un groupe contrôle et un groupe PV a rapporté une baisse du glucose sanguin sans changement d'insuline ni de glucagon ainsi qu'une augmentation du glucose sanguin dans les muscles pour les deux groupes (Di Loreto et al., 2004).

Bref, il est très difficile de tirer des conclusions sur les effets des entraînements PV sur les systèmes neuroendocriniens et neuromusculaires à cause des différences énormes des protocoles, des groupes et des sujets.

1.6 Les adaptations chroniques à l'entraînement par vibration

Les adaptations chroniques de l'entraînement PV ont beaucoup été étudiées au fil des années. Les caractéristiques de ces recherches longitudinales diffèrent beaucoup pour ce qui est de la fréquence, de la durée de l'exposition, de l'amplitude, et de la durée du programme. Or, il y a certaines améliorations qu'apporte l'entraînement PV qui ne peuvent être ignorées.

L'entraînement PV apporte des améliorations significatives aux sauts contre-mouvements (CMJ; saut avec une phase négative) ainsi qu'aux sauts de type squat (SJ; saut sans phase négative). Il existe une différence significative entre le CMJ et le SJ qui est attribuée au cycle étirement-détente (SSC). Il semblerait donc que l'entraînement PV provoque des modifications positive du SSC (Rehn, Lidstrom, Skoglund, & Lindstrom, 2007). On retrouve le SSC lors du CMJ; c'est l'étirement du muscle avant la phase de raccourcissement. Lorsque le muscle est étiré, il y a un emmagasinement d'énergie élastique qui avec l'activation du réflexe d'étirement cause une augmentation maximale du recrutement du muscle sur une période de temps minimum. Il est bien connu que les fibres à contraction rapide servent de médiateur au cycle étirement-détente (Rittweger et al., 2000). Pour cette raison, on pourrait supposer qu'il y a une adaptation des fibres de type II et une augmentation du recrutement de ces fibres suite à l'entraînement PV. Cependant plusieurs études n'ont constaté aucunes améliorations du SJ ou du CMJ après un entraînement PV (Delecluse, Roelants, Diels, Koninckx, & Verschueren, 2005; Di Giminiani, Tihanyi, Safar, & Scrimaglio, 2009).

Petit et al. 2010 ont investigué les effets d'un entraînement PV de 6 semaines avec des variations de fréquences et d'amplitudes chez les hommes modérément actifs. Tous les sujets ont été assignés au hasard soit dans le groupe haute fréquence/haute amplitude (50Hz, 4mm), soit dans le groupe basse fréquence/basse amplitude (30Hz, 2mm), soit dans le groupe contrôle (sans vibration). Une amélioration significative de la détente n'a été trouvée que chez le groupe de haute fréquence/haute amplitude alors qu'aucun changement n'a été constaté chez le groupe de basse fréquence/basse amplitude. Une autre étude a déterminé que des entraînements de 8 semaines utilisant la même accélération mais différentes fréquences et amplitudes peuvent similairement et significativement améliorer le CMJ. Ils ajoutent que les adaptations neuromusculaires dépendent des paramètres de vibration employés (C. H. Chen, Liu, Chuang, Chung, & Shiang, 2013). Les futures recherches devraient s'intéresser à étudier les effets des vibrations de non seulement différentes fréquences et amplitudes mais aussi différentes accélération.

Une étude récente a montré qu'un entraînement PV de 10 semaines à une fréquence de 2 fois par semaine chez les femmes obèses (IMC $35 \geq 40 kg/m^2$) améliore leurs composition corporelle et force musculaire (Milanese et al., 2013). En 2004, Roelant et collègues (2004) ont comparé la force musculaire ainsi que la composition corporelle suite à un entraînement de 24 semaines chez des femmes non entraînées. Les résultats post-entraînement n'ont démontré aucun changement de poids corporel et de pourcentage de masse grasse entre les 2 groupes. Par contre, il y avait une augmentation du pourcentage de masse maigre chez le groupe PV de +2.2%. (Roelants et al., 2004). Qu'est-ce qui pourrait expliquer cette augmentation de masse maigre? Kvorning et al. (2006) ont montré une augmentation significative de la concentration plasmatique de testostérone, d'hormone de croissance et de cortisol après 9 semaines d'entraînement PV (Kvorning et al., 2006). Bosco et al. (2000) ont aussi constaté une augmentation de la concentration plasmatique de testostérone ainsi que d'hormone de croissance après une session de 10 minutes d'entraînement PV chez de jeunes sujets actifs. Une étude chez les femmes obèses a également démontré une augmentation de la concentration plasmatique de l'hormone de croissance après une session d'entraînement PV (Giunta et al., 2012). L'augmentation de la concentration plasmatique de testostérone ainsi que d'hormone de croissance après un entraînement PV peut avoir un effet anabolique qui se traduit par l'hypertrophie des muscles (Bosco et al., 2000). Par contre, certaines études n'ont pas pu trouver les mêmes résultats (Cardinale et al., 2006; Erskine et al., 2007). Une étude chez les jeunes rats suggère l'hypertrophie des fibres de type I et l'hypertrophie ainsi que l'hyperplasie des fibres de type II par la vibration de basse magnitude (Xie, Rubin, & Judex, 2008). Il serait important de mieux comprendre les effets de l'entraînement PV chez l'humain et ses effets sur la masse maigre, car il peut y avoir des répercussions sur le métabolisme de base.

Peu de travaux ont comparé les effets de l'entraînement PV à l'entraînement contre résistance traditionnel. Quelques études suggèrent que ces deux modalités améliorent de manière similaire la force isométrique et isocinétique (A. Bogaerts et al., 2007; Delecluse, Roelants, & Verschueren, 2003; Roelants, Delecluse, Goris, & Verschueren, 2004). Une étude a montré une amélioration significative de la détente après l'entraînement PV mais non avec l'entraînement contre résistance traditionnel chez les jeunes femmes non entraînées (Delecluse et al, 2003). Kvorning et al, en 2006, ont démontré que l'entraînement sans vibration chez les sujets actifs entraîne une plus grande augmentation de la force isométrique du quadriceps mesurée lors d'un exercice d'extension de la jambe et de la détente, comparée à l'entraînement PV (Kvorning, Bagger, Caserotti, & Madsen, 2006). Dernièrement, une étude a démontré que l'entraînement PV chez les femmes modérément actives entraine une augmentation de force des fléchisseurs du genou qui n'est pas présente chez le groupe contrôle (Karatrantou, Gerodimos, Dipla, & Zafeiridis, 2012). D'autres études ont démontré une amélioration de la puissance musculaire en combinant les exercices de résistance avec les vibrations (Issurin, Liebermann, & Tenenbaum, 1994). Il faut noter que ces deux dernières études ont utilisé des sujets déjà très entraînés et que les protocoles d'entraînement de toutes ces études différaient beaucoup. Les résultats contradictoires trouvés dans la littérature pourraient aussi être causés par l'incohérence des modalités d'entraînement. Les prochaines recherches devraient donc avoir comme objectif de comparer les effets de l'entraînement PV avec ceux de l'entraînement traditionnel en résistance chez les gens entraînés et non entraînés.

1.7 Les femmes en surpoids et le déconditionnement

Au cours des dernières décennies, il y a eu une augmentation de la prévalence de l'obésité dans le monde entier. Il est bien établi que le surpoids (IMC $\geq$ 25 kg/m^2) ou obésité (IMC $\geq$ 30 kg/m^2) mènent à des risques accrus tel que l'hypertension, le diabète de type 2, les accidents vasculaires cérébraux, les maladies coronariennes et certains cancers (Crespo, Keteyian, Heath, & Sempos, 1996). Une forte corrélation a été établie entre le surpoids / l'obésité et le manque d'activité physique. À long terme, ce manque d'activité physique cause à cette population déjà vulnérable plus d'efforts pour compléter un exercice quelconque. Cet effort amplifié est accompagné par une hypoactivité qui est suivie par la peur de l'activité physique ou de l'inconfort/douleur qui y est rattachée. L'hypoactivité réduit les capacités physiques et l'activité physique devient de plus en plus difficile. Tout cela mène à un gain de poids qui contribue à l'obésité (Frankish, Milligan, & Reid, 1998). Ce cercle vicieux est mieux connu sous le nom de syndrome de déconditionnement. La fatigue étant associée à l'obésité et à la réduction des niveaux d'activités physiques recommandés touche beaucoup cette population et contribue au syndrome de déconditionnement (Resnick, Carter, Aloia, & Phillips, 2006).

De nombreuses études ont rapporté que les femmes ont tendance à souffrir davantage du syndrome de déconditionnement que les hommes (Crespo et al., 1996; Yoshida, Allison, & Osborn, 1988). Pourquoi les femmes seraient-elles plus à risque de souffrir de ce syndrome que les hommes? La réponse à cette question, bien qu'importante, n'est pas encore étoffée. L’activité physique intense a été négativement corrélée à l'adhésion, ce qui pourrait être dû au fait qu’un exercice de haute intensité soit souvent ressenti comme désagréable (Crisp, Fournier, Licari, Braham, & Guelfi, 2012; Perri et al., 2002). Quant à lui, l'utilisation d'une plateforme de vibration est considéré un entraînement de basse intensité et un entraînement alternatif à l'entraînement de force (Rittweger, 2010). Cet entraînement pourrait être une manière plus convenable de commencer un entraînement physique pour les gens qui ont de la difficulté à faire de l’exercice comme les femmes qui souffrent d’embonpoint.

1.8 L’énoncé de thèse

Nous retrouvons de nombreux articles dans la littérature sur les effets d’un entraînement en vibration sauf que peu d’études ont été effectuées pour analyser les effets chroniques d’un entraînement sur plateformes vibrantes chez les femmes en surpoids. L’objectif de cette étude est donc de déterminer les adaptations neuromusculaires, physiologiques ainsi que les modifications de la fatigabilité suite à un entraînement de 6 semaines sur plateforme vibrante chez les jeunes femmes adultes en surpoids.

1.9 Questions de recherche

Un programme d’entraînement de 6 semaines sur plateforme vibrante chez les jeunes femmes en surpoids apporte-t-il des adaptations neuromusculaires et physiologiques plus prononcées qu’un même entraînement sans vibration?

1.10 Hypothèses

I. L’entraînement sur plateforme vibrante entrainera une augmentation de la force musculaire et de la puissance musculaire qui sera supérieure au groupe contrôle.

II. L’entraînement sur plateforme vibrante entrainera une augmentation de masse maigre et une réduction de la masse grasse qui sera supérieure au groupe contrôle.

III. L’entraînement sur plateforme vibrante entrainera une amélioration des composantes de fatigue sensibles aux modifications physiologiques qui sera supérieure au groupe contrôle.

IV. L’entraînement sur plateforme vibrante entraînera une réduction de l’index de fatigue ainsi qu’une réduction de la perception de fatigue générale qui sera inferieurs au groupe contrôle.

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CHAPITRE 2: MANUSCRIT 1

THE EFFECTS OF A SIX-WEEK WHOLE BODY VIBRATION TRAINING PROTOCOL ON THE PHYSICAL CAPACITIES OF OVERWEIGHT YOUNG FEMALE ADULTS

Introduction

The prevalence of obesity has increased worldwide over the past few decades (Consultation, 2000). It is also well established that being overweight (BMI ≥ 25kg/m^2) or obese (BMI ≥ 30kg/m^2) is linked to adverse health effects (Tremblay, Katzmarzyk, & Willms, 2002). Statistics Canada has reported that the prevalence of hypertension, type 2 diabetes, stroke, coronary heart disease and several cancers more than quadrupled from 5% to 21% among men, and from 6% to 31% among women between 1981 and 2009 (Statistics Canada, 2010). During the same timeframe, decreased fitness levels in young adults (aged 20-40) have also been documented (Statistics Canada, 2010). Being overweight or obese is strongly correlated with sedentary behaviors (Mozaffarian, Hao, Rimm, Willett, & Hu, 2011; Shields & Tremblay, 2008).

Excess weight usually makes exercising more effortful for overweight and obese populations compared to normal weight populations. Accordingly, the need to exert greater effort during exercise may lead to exercise and physical activity avoidance (hypoactivity) in this already vulnerable population, which may be attributable to the fear of painful and unpleasant exertion. This state of hypoactivity places individuals at greater risk of further weight gain (Frankish et al., 1998). This vicious cycle of limited exercise/physical activity associated with weight grain is better known as the deconditioning syndrome or the disuse syndrome (Frankish et al., 1998). The prevalence of deconditioning syndrome is reported to be typically greater in women than in men (Crespo et al., 1996; Yoshida et al., 1988). The reasons why women are more impacted than men are not completely understood. The overweight population may be more easily fatigued than the normal weight population. Accordingly, they may be unable to undertake an intense aerobic training program but could start with a low intensity strength program to build up muscle and increase muscle fatigue resistance. Increasing muscle strength can improve physical activity adherence and decrease muscle fatigability, in other words improve overall physical fitness and health.

Whole body vibration (WBV) training is a relatively new training technique offered in most gyms where subjects perform exercises on a vibrating platform. The basis of this type of exercise is that the mechanical vibrations induce non-voluntary muscle contractions. This training technique does not necessarily improve cardiovascular capacity but is said to improve muscle strength and power (Rehn et al., 2007; Rittweger et al., 2000; Roelants et al., 2004). For example, muscle power has been shown to increase in postmenopausal women subject to vibration exercise on a platform twice a week for 6 months (Russo et al., 2003). Studies have also shown that resistance training improves insulin sensitivity, HDL cholesterol, increases muscle strength and lean body mass (Shaibi et al., 2006; Willis et al., 2012; Winett & Carpinelli, 2001). WBV is a submaximal training technique and is safe for overweight individuals that might have cardiovascular problems (Milanese et al., 2013). This type of training has the potential to increase muscle mass in overweight and obese populations that can be advantageous in these individuals that have pre-diabetes or diabetes.

The aim of this study was to examine the effects of WBV on body composition and physical capacities (isokinetic strength, power, muscle elasticity index) in overweight young female adults. We hypothesized that WBV would increase fat free mass (FFM) as well as elasticity index, leg power and strength.

Methods

Participants and study design

Twenty-four overweight young female adults (body fat percentage 30-35%) between the ages of 20 and 40 volunteered and were randomly assigned to 2 groups. Fourteen participated in the whole body vibration group (VIB) and ten in the control group (CON). Eligibility for participation was based on a screening questionnaire (PAR-Q) and a medical examination. The exclusion criteria were the presence of infectious disease, diabetes, acute hernia, joint problems or pregnancy. The Laurentian University Research Ethics Board approved this study and all participants gave written informed consent prior to testing. This study consisted of six weeks of training and four testing sessions; 2 before (sessions 1 & 2) and 2 following (sessions 3 & 4) the training regimen.

Experimental procedure

Subjects trained 3 times a week under supervision to assure exercises were performed correctly. Sessions lasted 30 minutes and entailed 15 sets of 1-minute exercises followed by 1-minute rest intervals. One set consisted of 15 controlled and timed squats (15 flexion and extension per minute) with no weight resistance. Participants stood feet shoulder width apart, trunk straight and knee angle fluctuating from 90° (flexion) to 160° (extension). The VIB group performed their exercises on the power Plate® pro 6. Vertical vibration amplitude settings were kept on low (2mm) throughout the entire 6 weeks as frequency was set at 30Hz for weeks 1-3 and increased to 35Hz for weeks 4-6. The CON group performed the same exercises without vibration. Basal metabolic rate, body composition, squat jumps, countermovement jumps, and

Wingate test were performed during sessions 1 and 3 and isokinetic tests were done during sessions 2 and 4.

Training experience

The participants reported no adverse side effects. One participant of the VIB group dropped out as a result of injuries not related to the training. All twenty-three remaining subjects completed 18 sessions in 6 weeks.

<u>Assessment</u>

The exercise and experimental protocols consisted of 6 weeks of training and of 4 testing sessions; sessions 1 and 2 were completed pre training and sessions 3 and 4 were completed post training (table 2.1).

Table 2.1. Name of tests completed in each session.

	Sessions 1 & 3	Sessions 2 & 4
Tests	Basal Metabolic Rate Hydrostatic weighing Wingate Squat and countermovement jumps	Isokinetic

Basal Metabolic Rate (BMR)

The BMR was measured first thing in the morning during sessions 1 and 3, on subjects that were required to fast ≥12 hours prior to testing. All reported no strenuous physical activity 24h prior to testing. Height and weight were measured with a stadiometer (Holitain Limited) and scale (Health-O-Meter), respectively. Participants were equipped with a canopy mask connected to a portable spirometer system (VmaxST, Sensormedics, USA). Participants remained in a supine position throughout the test (30 minutes) and heart rate was recorded every minute with a Polar S160i heart rate monitor throughout the test. Equipment calibration was done before every test according to the manufacturer's recommendations.

Body composition

Weight (kg), height (cm) and vital capacity (L) were measured before hydrostatic weighing (HW). Participants were seated in a chair submerged in the hydrostatic tank. Following a deep exhalation, subjects were immersed under water while loading sensors connected to a computer calculated body composition. Measurements were taken five times and 3 measurements were kept for analysis, as we did not make use of the highest and lowest measurements. Body fat percentage was calculated using Archimedes principle and using the formula developed by Siri (Siri, 1956) and correcting for residual lung volume.

Squat jump and countermovement jump

Jumps were performed on an AMTI force platform (AMTI PB400-600). Two types of jumps were used to evaluate motor skills: a countermovement jump (CMJ; eccentric and concentric phases) and a squat jump (SJ; concentric phase only). Two trials were performed for each jump with rest time of one minute between trials. The order of the jumps was randomized and the highest jump measurement was retained for the analysis. The Elasticity Index (EI) was determined using the following formula: EI= (CMJ-SJ)/SJ*100. (Walshe, 1996)

Wingate Anaerobic Test (30 second test)

The Wingate test (Dotan & Bar-Or, 1983), a high resistance 30s cycling test that measures maximal and mean power output, was performed on a modified ergocycle where distance traveled and workload were measured. Signals were then transformed and the average power was calculated for every second of the test. Initial resistance was set according to each participant's body weight (0.075 $g*kg^{-1}$) (Dotan & Bar-Or, 1983).

Isokinetic

During sessions 2 and 4, muscle strength and torque were assessed with an isokinetic ergometer (Biodex System 3. Shirley Corporation. NY. USA). Instant torque at any given angle was recorded and validity was confirmed (Taylor, Sanders, Howick, & Stanley, 1991). Subjects were seated on the Biodex with the rotation axis of the knee in alignment with the lever arm of the ergometer.

Participants performed 3 types of contractions during knee extension and flexion.

1. Concentric (Con): 3 knee extensions and 3 knee flexion at 60°/second, 120°/second and 180°/ second. During concentric contractions, the knee angle varied from 90° to 170°.
2. Eccentric (Ecc): 3 knee extensions and 3 knee flexion resisting the biodex movement at 60°/second, 120°/second and 150°/second. During eccentric contractions, the knee angle varied from 90° to 170°.
3. Isometric (Iso): at 90° without movement with 2 tries in extension and 2 tries in flexion.

During these tests, torque produced at the knee joint (Biodex) and electromyography activity (EMG) of the principal leg muscles [Vastus Lateralis (VL), Vastus Medialis (VM), Rectus Femoris (RF) and Biceps Femoris (BF)] were recorded. The electrodes were preamplified (type Medicotest blue sensor M-00-S, 27 mm diameter) with a sampling frequency of 2048 Hz.

The highest peak torque of each contraction was used for analysis. Muscle strength and torque were determined by processing the data using MATLAB® (Version 7.9.0, Mathworks™, Natick, MA).

Nutritional and physical activity journals

Participants were asked to record their food intake and physical activity during 3 days (2 days between Monday to Friday and 1 day during the weekend (Saturday/Sunday)). The journals were completed during the first and last week of training. Measurements of participants' pre and post average physical activity energy expenditure and caloric intake were calculated using Nutribase™11. Participants were also asked not to change their nutritional and physical activity habits during the course of the study.

Statistical analysis

Statistical Package for the Social Sciences (SPSS 16.0) was used for statistical analyses. Following a normality test, an ANOVA (group x time; time being pre vs. post training) with repeated measures was performed to analyse the effect of the training program and time. If main effects or interactions were found, Tukey's HSD was used as a post-hoc test. All values were reported as mean ± standard deviation (SD). The level of significance was set at $p < 0.05$.

Results

BMR and body composition

No significant differences in basal metabolic rate were found between the VIB and CON groups at baseline (Table 2.2, $p>0.05$). The main effect of time was significant for body fat mass ($F=13.59$; $p<0.01$) and body fat percentage ($F=14.78$; $p<0.01$); post-hoc analyses revealed that body fat mass and body fat percentage were significantly higher for the VIB group in both pre and post training. No other significant changes were found ($p>0.05$).

Table 2.2. Basal metabolic rate and anthropometric variables at baseline (pre) and post-training. Values are mean ± SD, *p < 0.05, ** p < 0.01; significantly different from control group.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Age (years)	23.3±3.4		23.3±3.3	
Height (cm)	1.67±0.07		1.66±0.1	
Weight (kg)	80.3±13.3	80.0±12.7	77.9±9.6	77.3±9.6
BMI (kg/m^2)	28.5±3.2	28.4±3.1	28.1±2.2	27.9±1.6
Body fat %	35.2±3.6**	34.2±3.7*	32.3±3.5	31.1±3.2
Body fat mass (kg)	28.5±7.4**	27.3±7.2**	25.1±4.6	24.1±3.4
FFM (kg)	51.6±6.1	51.9±6.8	52.3±5.2	53.2±5.7
Basal metabolic rate (kcal/24h)	1635.6±229.2	1574.3±233.5	1517.0±188.8	1503.0±197.2

BMI: Body mass index

Jump performance and Wingate

No significant differences in CMJ, SJ or EI between VIB and CON groups or over time were found ($p>0.05$) (Table 2.3). Jump performance was not affected by WBV. Similarly, there were no significant differences in maximal power output or mean power output between the VIB and CON groups at baseline or overtime (p>0.05). Maximal and mean power outputs were not improved by WBV (p>0.05).

Table 2.3. Squat jump, countermovement jump, and elasticity index values at baseline (pre) and post-training. Values are mean ± SD.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
SJ (cm)	18.19±2.94	18.37±3.09	21.27±2.88	20.99±2.67
CMJ (cm)	20.66±2.75	21.43±2.85	24.01±2.69	23.85±3.04
EI (%)	11.81±7.72	14.41±7.06	11.43±6.95	11.79±6.68

SJ: squat jump; CMJ: countermovement jump; EI: elasticity index

Dynamic and isometric strength

There were no significant changes in isometric strength measurements pre and post training for either the VIB or CON groups (figure 2.1 and 2.2). For dynamic strength measures, a significant decrease of 22.7% in maximal torque was observed for the VIB group during eccentric contraction at 120°/s for knee extensions (F=5.69; p=0.028) whereas this measure remained unchanged for the CON group (figure 2.1). Similarly, a significant reduction in maximal torque was found for the VIB group post-training during the concentric contraction at 120°/s (17.2%, F=6.32; p=0.02) and at 180°/s (20.7%, F=16.75; p=0.001) for knee flexion whereas these measures were not altered in the CON group (figure 2.2). All other measures of dynamic strength were not significantly changed as a result of the training regimen with or without WBV.

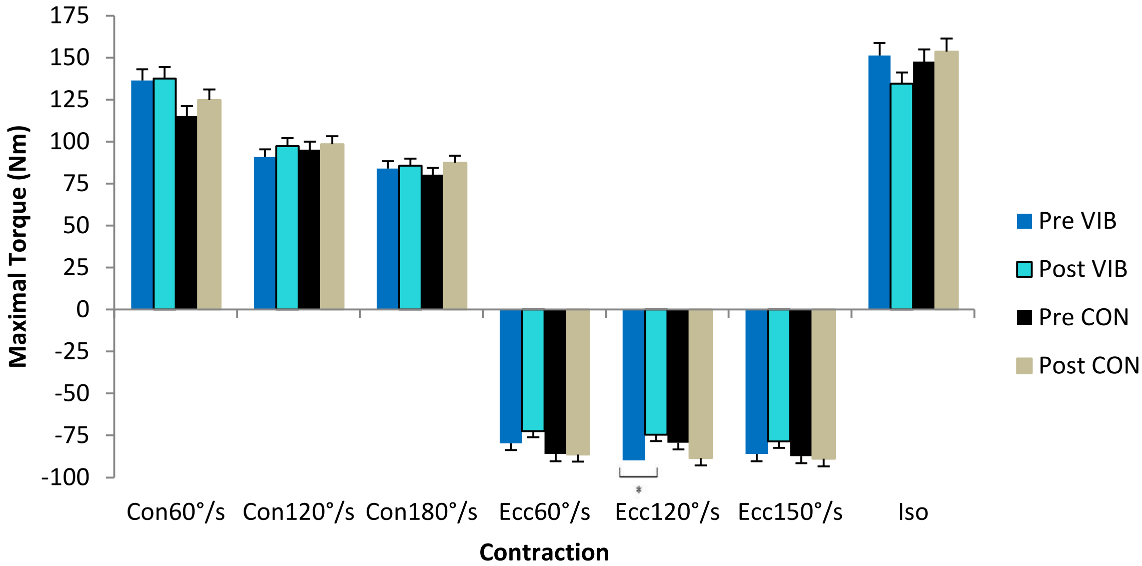

Figure 2.1. Maximal torque-velocity relation in extension before and after 6-week training for both VIB and CON groups. Values are mean ± SD, *$p < 0.05$.

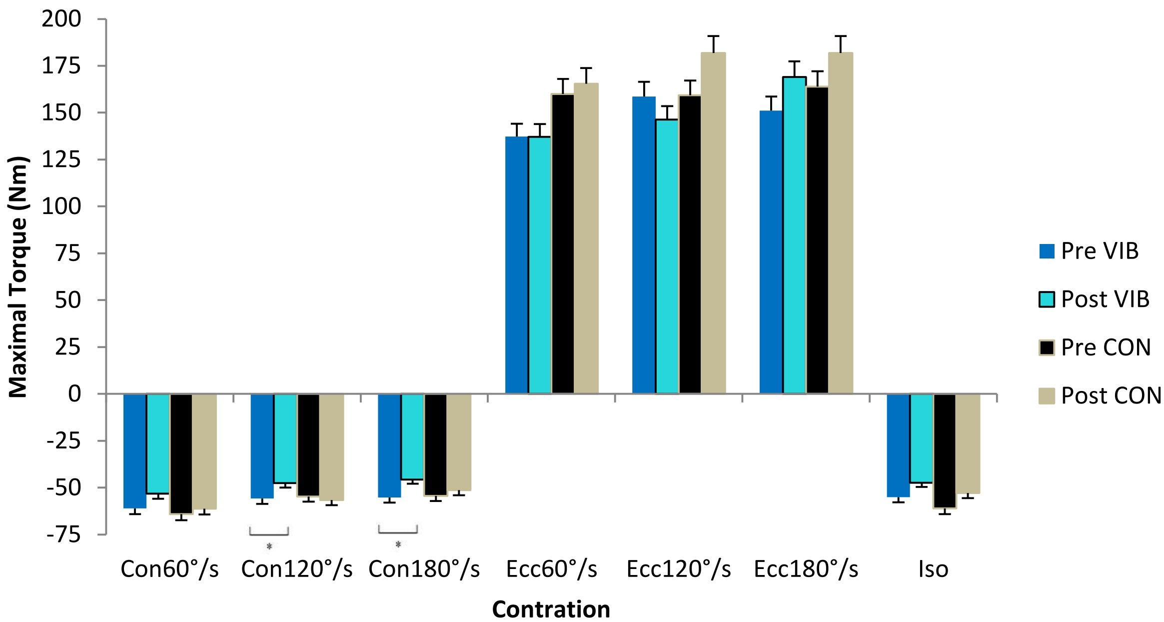

Figure 2.2. Maximal torque-velocity relation during contractions in flexion before and after 6-week training for both VIB and CON groups. Values are mean ± SD, $p < 0.05$.

Nutritional and physical activity journals

Physical activity/energy expenditure levels and nutritional journals (nutritional data not shown: Appendix A) at baseline were found to be similar between the VIB and CON groups ($p>0.05$). However, energy expenditure levels post-training were significantly increased in both groups ($F=18.79$; $p<0.001$; figure 2.3). No other significant changes were found ($p>0.05$).

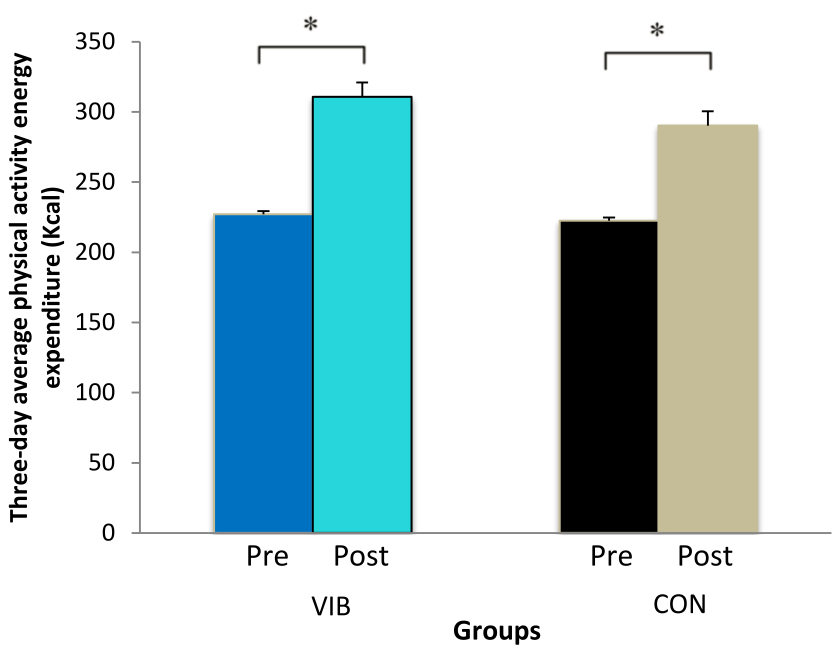

Figure 2.3. Three-day average physical activity energy expenditure in kcal, pre and post 6-week training for both VIB and CON groups; *$p < 0.05$.

Discussion

The aim of this study was to investigate the effects of WBV training on body composition, dynamic and isometric strengths of leg muscles, jump performances and maximal power outputs in overweight young female adults. Despite the growing popularity of WBV training as an alternative to traditional training, our findings indicate that WBV training, at least with the vibration parameters tested herein, does not improve physical capacities of overweight young female adults.

Body weight and FFM were not significantly modified by the training protocol for either VIB or CON groups. This outcome is not surprising and is in fact in accordance with studies that have found WBV training to be an insufficient stimulus for improvements of body weight (Roelants et al., 2004) and FFM (Milanese et al., 2013). No change in body fat mass or body fat percentage were found in either groups although analyses of the physical activity logs suggest that the average daily energy expenditure was increased by 30% at the end of the training regimen for both VIB and CON groups ($p<0.001$).This result was expected as some studies have reported no significant difference in both body fat mass and body fat percentage as a result of vibration exercise (Roelants et al., 2004).

No significant modification of BMR was observed for either the VIB or CON groups in the present study. In one study, a small increase in oxygen consumption of 4.5ml $0_2 \bullet kg^{-1} \bullet min^{-1}$ was reported during WBV training when the vibration frequency was set at 26Hz (Rittweger, Ehrig, et al., 2002). Oxygen consumption levels of 4.5ml $0_2 \bullet kg^{-1} \bullet min^{-1}$ are equivalent to the metabolism requirements at moderate walking pace thereby suggesting that WBV training likely has very limited effects on aerobic fitness. As some WBV studies report an increase in strength, one could think that WBV also increases BMR by increasing FFM. BMR accounts for 60-70% of total energy expenditure. Therefore increases in the BMR can have a positive effect on health by potentially impacting body composition (Ferraro et al., 1992). In particular, it has been well documented that a high correlation exists between BMR and FFM and that skeletal muscle metabolism is an important constituent of BMR (Webb, 1981; Zurlo, Larson, Bogardus, & Ravussin, 1990). The WBV training protocol used in the present study was not effective in significantly increasing FFM; therefore notable differences in BMR were not probable. The present study entailed training 3 times a week. Furthermore, total WBV exposure and exercise lasted 15 minutes per session and was insufficient to trigger a significant increase in BMR. Considering that sedentary lifestyle was not an inclusion criterion and that our subjects were considered overweight but that some of them were moderately active, it is likely that our vibration settings were not intense enough.

Regarding the impact of WBV on SJ and CMJ, our results suggest that this type of exercise or at least the vibration parameters selected, did not improve these jumps. Our findings are in line with some studies but are in contrast with observations made in other studies looking at the benefits of WBV on untrained subjects (A. Bogaerts et al., 2007; Cochrane, Legg, & Hooker, 2004; Delecluse et al., 2005; Di Giminiani et al., 2009; Petit et al., 2010). Subjects undertaking WBV training with the following parameters; frequency 35 ≥ 50Hz, amplitude 2 ≥ 5mm and training 3 times a week tend to experience improvements in power. Perhaps the discrepancy between the present study and the results reported in literature is that the vibration parameters were not sufficiently intense to cause a change. Our Wingate results, which provide measures of anaerobic power of short duration during cycling, also lead us to conclude that our WBV training regimen had no impact on power.

Petit et al., (2010) investigated the effects of several 6-week WBV training programs with different frequency and peak-to-peak displacement settings on knee extensor muscle strength and power in men. All subjects were randomly assigned to a high-frequency/high peak-to-peak displacement group (HH; 50 Hz, 4mm), a low-frequency/low peak-to-peak displacement group (LL; 30 Hz, 2mm) or a SHAM training group. Significant improvements in jump performances were found only for the HH group. No significant differences in jump performances were found in the LL or SHAM group (Petit et al., 2010). When looking at the different groups of this latter study, our vibration setting can be considered low-frequency and low peak-to-peak displacement. Perhaps the lack of significant improvement in squat jump and countermovement jumps in our study is simply due to the vibration frequency and amplitude not being high enough to cause an effect. Moreover, power-training exercises normally elicit fast muscle contractions with external loads of about 50-70% of maximal strength. Numerous studies have showed that WBV training can in fact increase lower limb power without external loads or fast muscle contraction (Adams et al., 2009; Di Giminiani et al., 2009; Rees, Murphy, & Watsford, 2008). A study in 2009 suggested that greater responses to vibration exercise are produced when vibrations are individualized as opposed to being set at a fixed pre-selected frequency. This study was composed of a fixed vibration group, a control group and an individualized vibration group. The vibration setting for the individualized group was selected by monitoring the RMS values (Di Giminiani et al., 2009). In our study, the vibration stimulus (frequency and amplitude) may have been suboptimal resulting in no improvements in leg power in overweight young female adults. Our vibration stimulus parameters were selected based on our review of parameters available in the scientific literature and these parameters were not individualized. It may be possible to optimize the vibration stimuli for each participant by taking into account the EMG response associated with specific vibration protocol parameters. This may be an avenue of future research endeavors.

Dynamic strength measures were significantly reduced in extension during ecc120°/s and in flexion during con120°/s and con180°/s parameters. This result is not in accordance with the literature and was not expected. However, some studies investigating the acute effect of WBV with low frequencies and peak-to-peak displacements reported decreased voluntary muscle activation of the knee extensors (Colson, Petit, Hebreard, Tessaro, & Pensini, 2009; Jordan, Norris, Smith, & Herzog, 2010). These data parallel the reduction of strength found in this study as our settings were considered low frequency, and low peak-to-peak displacement. It has been reported that low amplitude/low peak-to-peak vibration settings have limited effects on muscle strength and that high amplitude and peak-to-peak displacements produce greater improvements in muscle strength and power (Marin & Rhea, 2010). It is probable that our vibration parameters were not optimal to increase knee extensor muscle strength after the training program. Unexpectedly, the present study shows that WBV training adversely affects dynamic strengths at high speeds whereas dynamic strengths at low speeds or during isometric contractions remained unchanged.

In summary, this study showed that WBV training at 30-35 Hz and low amplitude was an ineffective method to improve dynamic and isometric strengths, jump performances and maximal power outputs in overweight young female adults. These results show that vibration has no positive effect when compared to the control exercise group. The initial physical activity level of participants should be taken into consideration and not just their body composition. Perhaps future studies should investigate the efficacy of WBV training programs with individualized vibration settings in overweight young female adults as opposed to pre-determined vibration settings. It is also possible that greater benefits of WBV training may be achieved in obese and morbidly obese populations. Caution should be used when drawing conclusions on the effectiveness of WBV training.

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CHAPITRE 3: MANUSCRIT 2

THE EFFECTS OF A SIX-WEEK WHOLE BODY VIBRATION TRAINING PROGRAM ON THE FATIGABILITY OF OVERWEIGHT YOUNG FEMALE ADULTS

Introduction

Obesity has become a growing epidemic affecting life expectancies and living standards (Ahima, 2011). The prevalence of obesity has rapidly increased in the past 20 years and is now a global health concern (He, Piche, Clarson, Callaghan, & Harris, 2010). This major public health issue is a significant risk factor for other ailments such as hypertension, type 2 diabetes, stroke, coronary heart disease, several types of cancers and is strongly correlated with the lack of physical activity (Crespo et al., 1996). Some studies have found that combined training programs have more effects than aerobic or strength training alone. Untrained, overweight individuals tend to have a low aerobic capacity. Increasing strength training is crucial to decrease fatigability in this population. Decreasing fatigability can increase an individual's overall physical fitness and indirectly increase aerobic capacity.

Fatigue during physical activity can be described as decreased muscle strength and/or power or an increased effort needed during exercise and physical activity (Gandevia, 2001). Furthermore, fatigue can affect quality of life and has been shown to be more prevalent in individuals that are obese (Resnick et al., 2006). For instance, body fat percentage has been reported to be an independent predictor of fatigue (Lim et al., 2005; Vgontzas, Bixler, & Chrousos, 2006). A lack of physical activity leads to increased effort to complete a given exercise. A by-product may be fear of practicing physical exercise or apprehension related to pain and discomfort associated with exercise training which in turn may further reduce the overall physical capacity levels potentially leading to weight gain. This cycle is better known as the deconditioning or the disuse syndrome and is reportedly more prevalent in women than in men (Verbunt et al., 2003). Interestingly, studies have reported that women also experience a greater degree of fatigue and higher fatigue perception than men (M. K. Chen, 1986; van Mens-

Verhulst & Bensing, 1997) even when age and body mass index (BMI) is matched (Valentine et al., 2009). One study revealed that the quadriceps of obese adults tend to be less fatigue resistant then non-obese adults during voluntary fatigue tests (Maffiuletti et al., 2007). Fatigue and obesity can both be curtailed by increasing overall physical activity.

Whole body vibration (WBV) training research has been the topic of many studies in recent years. This type of exercise training is performed on a vibrating platform and elicits non-voluntary muscle contractions generated by mechanical vibrations. WBV training can be considered low intensity exercise depending upon the vibration parameters and this intensity level may be advantageous and beneficial to at risk individuals. In particular, many studies have demonstrated that WBV training not only reduces fatigue but also increases muscle strength and power (Alentorn-Geli, Padilla, Moras, Lazaro Haro, & Fernandez-Sola, 2008; Roelants et al., 2004; Torvinen et al., 2002). For instance, a 6-week WBV program has been reported to significantly reduce fatigue compared to traditional training in women with fibromyalgia (Alentorn-Geli et al., 2008). Another study showed that muscle power in postmenopausal women was increased by having subjects stand on a vibration platform twice a week for 6 months (Russo et al., 2003). This type of low intensity exercise could positively impact exercise adherence in overweight and obese individuals and help break the deconditioning cycle.

The aim of this study is to examine the effects of a 6-week low-intensity WBV training program on fatigability in overweight young female adults. We hypothesized that WBV will decrease fatigue index of the lower limbs during the Wingate test, increase fatigue resistance, improve neuromuscular efficiency and decrease fatigue perception in overweight young female adults.

Methods

<u>Participants</u>

Twenty-four overweight young female adults (body fat percentage 30-35%) between the ages of 20 and 40 took part in this study. Participants were randomly divided into two groups; fourteen participated in the WBV group (VIB) and ten in the control group (CON). Eligibility for participation was based on a screening questionnaire (PAR-Q) and a medical examination. The exclusion criteria were the presence of infectious disease, diabetes, acute hernia or pregnancy. The Laurentian University Research Ethics Board approved this study and all participants gave written informed consent prior to undergoing testing.

<u>Experimental procedure</u>

The effects of 6-week WBV training on fatigability were examined in overweight young female adults. Subjects trained 3 times a week under supervision to ensure exercises were performed correctly. In the course of a session, 15 sets of 1-minute exercises with no resistance were performed; each set consisted of 15 controlled squats per minute followed by 1-minute of rest. Participants stood feet shoulder width apart, trunk straight and knee angle alternating between 90° (flexion) to 160° (extension). The VIB group performed their exercises on the power Plate®. Amplitude settings were kept on low (2mm) throughout the entire 6 week training protocol and frequency was set at 30Hz during weeks 1-3 and increased to 35Hz during weeks 4-6. The CON group performed the same exercises without vibrations.

<u>Assessment</u>

This study was composed of 6 weeks of training and of 4 testing sessions; sessions 1 and 2 were completed pre training and sessions 3 and 4 were completed post training (table 3.1).

Table 3.1. Name of tests completed in each session.

	Sessions 1 & 3	Sessions 2 & 4
Tests	Hydrostatic weighing Wingate Fatigue questionnaires	Isokinetic fatigue test

Body composition

During sessions 1 and 3, measurements of participants' weight (kg), height (cm) and vital capacity (L) were obtained before hydrostatic weighing (HW). Participants were asked to complete a deep exhalation before being submerged in the water tank and loading sensors connected to a computer calculated body composition. A total of five measurements were taken and only three measures were kept for analysis as we did not make use of the highest and lowest measurements. Body fat percentage, body fat mass and FFM were calculated using Archimedes principle and the formula developed by Siri with correction for residual lung volume (Siri, 1956).

Wingate Anaerobic Test (30 second test)

The Wingate test (Dotan & Bar-Or, 1983) on ergocycle was used to determine the fatigue index (FI). The Wingate is a 30-second anaerobic test that consists of pedaling at maximum speed against a predetermined load. In the present study, the initial load was determined according to the participant's body weight (0.075 g/kg). The FI was calculated using the following formula:

FI = [(Peak Power Output - Min Power Output)/Peak Power Output] x 100.

Muscle Fatigue Test

During sessions 2 and 4, muscle fatigue was assessed using an isokinetic ergometer (Biodex, Shirley Corporation, NY, USA) in accordance with previous research conducted on obese individuals (Maffiuletti et al., 2007; Thorstensson & Karlsson, 1976). Participants were seated on the isokinetic ergometer and the right lateral femoral condyle was aligned with the ergometer's lever arm. To produce knee extensor fatigue, subjects completed 50 maximal concentric contractions at 90°/s. Participants then completed isometric contractions in knee extension and flexion on the isokinetic ergometer to quantify their muscle fatigue resistance: at 90° with 2 trials in extension and 2 trials in flexion. During these tests, torque produced at the level of the knee joint (Biodex) and electromyography activity (EMG) of the principle leg muscles [Vastus Lateralis (VL), Rectus Femoris (RF) and Biceps Femoris (BF)] were recorded.

Torque assessment

During the fatigue protocol, the peak torque of each contraction (50 in total) was normalized by the maximum peak torque. The FI was then measured by the rate of decline of the normalized peak torque values starting with the highest value of the first 5 contractions and ending with the 50^{th} contraction (Moreau, Li, Geaghan, & Damiano, 2008; Pincivero, Gear, & Sterner, 2001). The average maximum peak torque of the last five contractions was also calculated.

EMG assessment

The EMG electrodes were preamplified (type Medicotest blue sensor M-00-S, 27mm diameter) and sampling frequency was set at 2048 Hz. For each subject, root mean square (RMS) values were normalized to the highest value of the 50 concentric contractions. Peak torque was divided by the corresponding RMS (Warren et al.) normalized value to obtain neuromuscular efficiency (NME) (Bigland-Ritchie, Furbush, & Woods, 1986). NME modifications have been employed to determine if the mechanisms occurring during fatigue are of peripheral and/or of central origins. RMS and torque were processed using MATLAB® (Version 7.9.0, Mathworks™, Natick, MA). Following this fatigue protocol, the 15-point Borg questionnaire was administered to the subjects to quantify their rate of perceived exertion.

Fatigue Perception Questionnaires

Fatigue was also measured using three questionnaires (Appendix B) that were administered before and after the 6-week training protocol. The goal was to identify whether the vibration exercise protocol could curtail fatigue perception. The Fatigue Severity Scale (FSS) is a 9-item, one-dimensional questionnaire that detects changes in fatigue level (Krupp, Larocca, Muirnash, & Steinberg, 1989). The items are scored on a 7-point scale where 1 indicates a strong disagreement and 7 a strong agreement with the statement. The average is then calculated; minimal score being 1 and maximal score 7. A score above 4 indicates fatigue and the average score for a healthy individual is 2.3± 0.7. The Multidimensional Fatigue Inventory (MFI) is a 20-item multidimensional questionnaire that covers 5 dimensions of fatigue: physical fatigue, mental fatigue, general fatigue, reduced motivation and reduced activity and can therefore be used to define the type of fatigue (Smets, Garssen, Bonke, & Dehaes, 1995). Scores per item run from 1 to 5 and a total score is calculated from each scale ranging from 4 to 20. A score above 13 indicates severe fatigue. Finally, the Short Happiness and Affect Research Protocol (SHARP) is a questionnaire composed of different parts of SF-36 (life quality associated to health), CES-D

(Center for Epidemiologic Studies Depression scale) and MUNSH (Memorial University of Newfoundland Scale of Happiness). It is a 12-item questionnaire that evaluates participants' subjective long-term and short-term wellbeing (Stones et al., 1996). Positive answers for items 1, 2,6,7,8 and 12 scored 1 point and -1 for the remaining items. Negative responses or items left blank scored 0. There are no specific cut off points but higher scores indicated higher subjective well-being and happiness.

Nutritional and physical activity journals

Participants were asked to record their food intake and physical activity during 3 days (2 week days, 1 weekend day). The journals were completed during the first and last week of training. Measurements of participants' pre and post average physical activity energy expenditure and caloric intake were calculated using Nutribase™11. Participants were also asked not to change their nutritional and physical activity habits throughout the study.

Statistical analysis

Statistical Package for the Social Sciences (SPSS 16.0) was used for statistical analyses. Following a normality test, repeated measures ANOVA was used to analyse the effect of the training program. Tukey's HSD test was used as a post-hoc when main effects or interactions were found. All values were reported as mean ± standard deviation. Statistical significance was set at $p < 0.05$.

Results

Body composition

Other than body fat mass and body fat percentage, no significant differences (p>0.05) in anthropometric measurements between the VIB group and the CON group were found at baseline (Table 3.2). The main effect of time was significant for body fat mass (F=13.59; p=0.002) and body fat percentage (F=14.78; p<0.001); post-hoc analyses revealed that body fat mass and body fat percentage were significantly higher for the VIB group in both pre and post training. (Table 3.2). No other significant changes were found (p>0.05).

Table 3.2. Anthropometric data at baseline and post-training. Values are mean ± SD, *p < 0.05, **p < 0.01.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Age (years)	23.3±3.4		23.3±3.3	
Height (cm)	1.67±0.7		1.66±0.1	
Weight (kg)	80.3±13.3	80.0±12.7	77.9±9.6	77.3±9.6
BMI (kg/m^2)	28.5±3.2	28.4±3.1	28.1±2.2	27.9±1.6
Body fat percentage (%)	35.2±3.6**	34.2±3.7*	32.3±3.5	31.1±3.2
Fat mass (kg)	28.5±7.4**	27.3±7.2**	25.1±4.6	24.1±3.4
FFM (kg)	51.6±6.1	51.9±6.8	52.3±5.2	53.2±5.7

BMI: body mass index; FFM: fat free mass

Muscle Fatigue Tests

The FI as measured using the Wingate test was significantly decreased in both VIB and CON groups after the 6-week training program (F=8.29; p=0.01; figure 3.1) indicating that both groups experienced an improvement in fatigue resistance. Therefore, the squat exercise in combination with vibration was of no further benefit compared to the squat exercise alone in modulating the FI as assessed using the Wingate test.

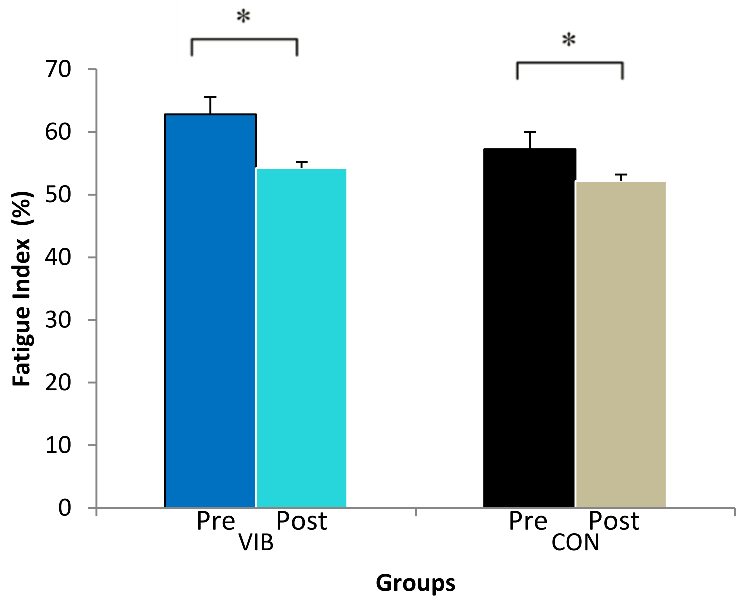

Figure 3.1. Fatigue index in % ± SD, pre (grey bars) and post (black bars) 6-week training for VIB and CON groups; * $p < 0.05$.

A significant interaction (F=13.201; p<0.001) was found for the normalized torque measured from the knee extensors during the isokinetic fatigue test. Specifically, normalized torque for the knee extensors was decreased post-training only for the CON group (F=15.515; p<0.001; figure 3.2A). In comparison, a significant decrease in normalized torque of the knee flexors during the isokinetic fatigue test was confirmed in both groups (F=74.898; p<0.001) but VIB group decreased significantly less than the CON group (figure 3.2B). As for the torque values of isometric contractions measured following the fatigue test, the decline was significantly less post-training for the VIB group in extension but no change was found in the CON group (F=6.257; p= 0.031) suggesting that the vibration exercise was beneficial.

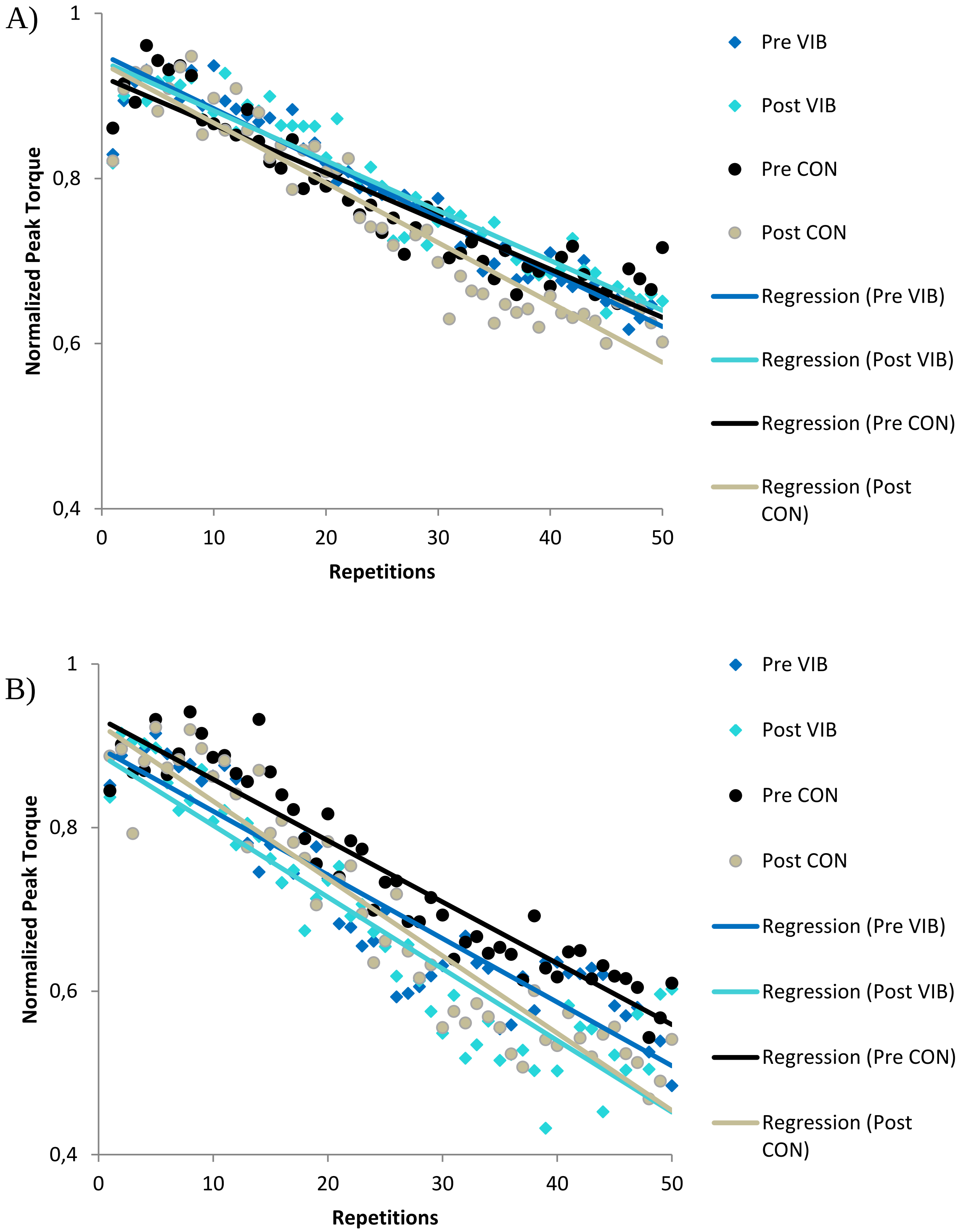

Figure 3.2. Normalized peak torque across all repetitions during the fatigue protocol pre/post training for (A) knee extensors and (B) knee flexors.

Torque regression slopes calculated only from the peak torque and average last five contractions and the average torque calculated from the last five contractions of the 50-contraction fatigue protocol were not significantly different between the VIB and CON groups ($p > 0.05$; table 3.3).

Table 3.3. Slope data from peak torque and average last five contractions during 50 contractions and the average normalized torque of the last five contractions. Data are mean ± SD in knee extension and in knee flexion.

		VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Extension	Slope	-0.82	-0.74	-0.61	-0.78
	AVG last 5 contractions	0.63± 0.15	0.66 ± 0.14	0.68± 0.09	0.65± 0.13
Flexion	Slope	-1.09	-0.87	-0.85	-0.91
	AVG last 5 contractions	0.53± 0.12	0.55± 0.10	0.57± 0.17	0.51± 0.14

As presented in Table 3.4, in both the extension and flexion phase of the fatigue test, no significant differences were found for the normalized RMS data for either the pre or post-training sessions or between the VIB and CON groups ($p > 0.05$).

Table 3.4. Normalized RMS of the Rectus Femoris (RF; extension), Vastus Lateralis (VL; extension) and Biceps Femoris (BF; flexion) during 50 contractions. Data are mean ±SD.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Normalized RF RMS (%) (extension)	0.71 ± 0.08	0.66 ± 0.16	0.64 ± 0.17	0.72 ± 0.11
Normalized VL RMS (%) (extension)	0.72 ± 0.15	0.73 ± 0.10	0.73 ± 0.07	0.73 ± 0.08
Normalized BF RMS (%) (flexion)	0.45 ± 0.15	0.51 ± 0.13	0.51 ± 0.17	0.50 ± 0.16

BF: Biceps Femoris; RF: Rectus Femoris; VL: Vastus Lateralis; RMS: root mean square

During the extension phases of the fatigue protocol, a decrease of NME was found post-training for the CON group for the VL muscle ($F = 5.831$; $p = 0.025$ but no change was observed for the VIB group (table 3.5). No other changes were found in extension. During the flexion phases of the fatigue protocol, a decrease of NME was found for the CON group for the RF muscle ($F=9.750$; $p = 0.005$) whereas no change was observed for the VIB group (table 3.5).

Table 3.5. NME of the Vastus Lateralis (VL; extension), Rectus Femoris (RF; flexion) during the fatigue protocol. Data are mean ±SD; *$p < 0.05$ between pre and post sessions within groups.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
VL NME (extension)	0.81 ± 0.18	0.93 ± 0.25	0.74 ± 0.27	0.65* ± 0.23
RF NME (flexion)	1.41 ± 0.79	1.46 ± 0.96	1.26 ± 0.44	0.39 * ± 0.17

VL: Vastus Lateralis; RF: Rectus Femoris; NME: neuromuscular efficiency

Questionnaires

Results from the FSS, MFI, SHARP or Borg questionnaires revealed no significant changes between pre and post-training between the VIB and CON groups ($p>0.05$; table 3.6). No significant differences in physical activity levels and nutritional journals between the VIB and CON groups were found at baseline ($p > 0.05$). However, physical activity energy expenditure was increased post training for both groups ($F = 18.79$; $p<0.001$, figure 3.3). No other significant changes were observed ($p>0.05$).

Table 3.6. FSS, MFI, SHARP and Borg questionnaires scores. Data are mean ±SD.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
FSS	2.83±1.06	3.10±1.10	3.01±1.03	2.99±0.75
MFI	12.75±3.90	12.6±4.28	12.62±2.89	12.22±4.43
SHARP	4.92±1.51	4.58±1.51	4.67±1.41	5.11±0.78
Borg	14.75±1.55	14.44±0.73	14.83±1.47	13.89±1.05

FSS: The Fatigue Severity Scale; MFI: Multidimensional Fatigue Inventory; SHARP: Short Happiness and Affect Research Protocol.

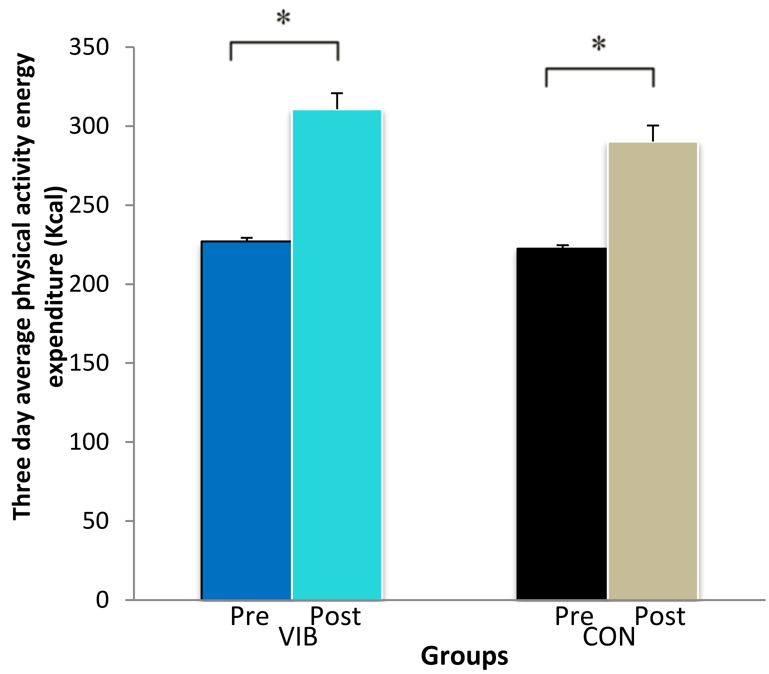

Figure 3.3. Three-day average physical activity energy expenditure in kcal ± SD, pre (grey bars) and post (black bars) 6-week training for VIB and CON groups; *p < 0.05.

Discussion

The present study was designed to examine the effects of a 6-week low intensity WBV training program on muscle fatigue and fatigue perceptions in overweight young female adults. We hypothesized that fatigue resistance would increase and fatigue perception would decrease after WBV training. The main findings of this study were that 6 weeks of low intensity WBV training significantly decreased the fatigue index as measured by the Wingate test, and decreased normalized torque of knee flexors as assessed during the fatigue protocol. Our findings suggest that fatigue resistance, although marginally improved following the training program, was no different between the VIB and CON groups. Furthermore, fatigue perceptions were not improved as a result of the training protocol either with or without vibration.

To our knowledge, this study is the first to examine the effect of low intensity WBV on the FI in overweight young female adults by using the Wingate Anaerobic Test. We observed a significant decrease in the FI in both VIB and CON groups indicating that WBV training was not of further benefit in mitigating muscle fatigue. A more detailed analysis revealed that this reduction in fatigue was not due to an increase in peak power output but rather to an increase in minimal power output. In line with this finding, a study showed that WBV does not increase muscle power in trained athletes (Delecluse et al., 2005). It would appear that the squat training protocol on its own, improved the fatigue resistance irrespective of the additional vibration stimuli, which in our study protocol was considered low-intensity (2 mm amplitude, 30 Hz frequency). The fact that participants in the VIB and CON groups experienced similar improvements in fatigue resistance either with or without vibration would suggest that 15-minute squat training 3 times a week for 6 weeks may be of benefit to overweight young female adults. Our findings do not rule out the possibility that additional benefits of vibration may be experienced if the vibration settings were set at higher intensities.

The torque rate of fatigue represented by torque regression slopes did change over time. It has been suggested that change in rate of fatigue is associated with maximal strength, muscle mass as well as the type of muscle fibres recruited (Kanehisa, Okuyama, Ikegawa, & Fukunaga, 1995; Lanza, Russ, & Kent-Braun, 2004; Pincivero, Gandaio, & Ito, 2003). A decrease in the rate of fatigue was found in the knee extensors only for the CON group. Furthermore, the rate of fatigue was found for the knee flexors of both VIB and CON groups but the reduction decreased significantly more. This study showed that the VIB group was more fatigue resistant compared to the CON group post training as shown by the torque rate of fatigue represented by torques regression slopes. Some studies have suggested that because of greater muscle mass, males are less fatigue resistant than women and that adults are less fatigue resistant than children (Kanehisa et al., 1995; Lanza et al., 2004; Pincivero et al., 2003). As there was no change increase in FFM or in muscle strength, it is not surprising that the rate of fatigue did not improve. To our knowledge, this is the first study looking into the effect of WBV training in overweight young female adults and results indicate that WBV has no effect on fatigue resistance in this population.

NME is the ratio of strength and EMG muscle activity (Milner-Brown & Miller, 1986). A reduction in NME with fatigue normally indicates that more motor units are used to generate the same amount of force and this was in fact observed in the CON group. Although previous studies have shown that WBV training tends to improve NME (C. Bosco et al., 2000; Furness & Maschette, 2009), our study showed no change in NME suggesting that there were no modifications in neural drive. It is possible that the vibration parameters used in this study were insufficient to improve NME in overweight young female adults.

Fatigue perception questionnaires were used in order to quantify subjective fatigue using a multidimensional approach. No changes were found in the FSS, MFI or SHARP questionnaire scores for pre/post training or between the groups. As a whole, our study has shown that WBV training at lower intensities, does not improve fatigue levels observed in overweight young female adults. Our results are in contrast with a study reporting that a 6-week WBV program completed twice a week decreases fatigue in women with fibromyalgia as measured using the visual analog scale. (Alentorn-Geli et al., 2008). To our knowledge, this is the first study looking at the effect of WBV training using the MFI and SHARP in overweight young female adults. Interestingly, our FSS results are in line with a study that found that WBV training had no effect on the FSS score (Maquet, 2007). There is an apparent discrepancy between the observed increase in average physical activity energy expenditure in both groups but no significant change in the MFI that measures activity as a dimension. The MFI measures 5 dimensions of fatigue and perhaps another questionnaire assessing the types of activities would have yielded more detailed information. The elevated energy expenditure measured post-training in both groups may have been the result of higher exercise intensity or longer exercise sessions rather than an increase in the number of daily exercises.

In conclusion, this study demonstrates that other than having beneficial effects on fatigue resistance compared to the CON group and decreasing the FI of lower limb muscles as assessed using the Wingate test, WBV training at 30 Hz and low amplitude has no other overt effects on fatigue perceptions in overweight young female adults. Future research could examine the efficiency of WBV training in overweight young female adults with different vibration parameters as vibration stimuli could have been too low or too high to have a positive effect on fatigue resistance and fatigue perceptions.

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CHAPITRE 4: DISCUSSION GÉNÉRALE

L'objectif de cette étude était d'évaluer les effets d'un entraînement de faible intensité sur une durée de 6 semaines utilisant une plateforme vibrante sur la composition corporelle, les adaptations neuromusculaires et physiologiques chez les jeunes femmes adultes en surpoids. Une discussion générale des résultats de cette étude sera présentée, ainsi que les limites de la méthodologie, les implications de ces résultats ainsi que les conclusions.

4.1 Entraînement PV, mesures anthropométriques et métabolisme de base

En résumé, cette étude a démontré qu'un entraînement PV de basse intensité de 6 semaines n'a eu aucun effet sur la composition corporelle et le métabolisme de base chez les jeunes femmes en surpoids (tableau 4.1). Il est possible que les paramètres de vibrations ne fussent pas optimaux pour créer des changements de mesures anthropométriques. Les paramètres de vibration doivent être mieux étudiés pour comprendre les effets de ces entraînements.

Tableau 4.1 Sommaire des résultats de composition corporelle et métabolisme de base.

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Masse grasse	↔		↔	
% de masse grasse	↔		↔	
IMC	↔		↔	
MB	↔		↔	

IMC : indice de masse corporelle; MB : métabolisme de base

Il est fort possible que l'exposition totale par semaine de vibration qui était de 45 minutes, l'intensité de l'entraînement et/ou la durée de l'intervention furent insuffisantes pour augmenter le métabolisme. La littérature démontre à maintes reprises que l'entraînement PV peut augmenter la force musculaire mais il ne faut pas penser que cela augmente nécessairement le métabolisme de base car les changements de force musculaire sont tout d'abord centraux; les changements morphologiques des muscles eux, peuvent prendre plusieurs mois pour se manifester (Rittweger, 2010).

4.2 Entraînement PV, sauts de type squat et sauts contre-mouvement

Il n'y a eu aucune amélioration des sauts de type squat et contre-mouvement chez les femmes en surpoids. L'entraînement en vibration ainsi que l'entraînement sans vibration ont tous deux eu aucuns effets sur les sauts. Dans la littérature, on rapporte que l'entraînement contre résistance traditionnel produit des augmentations dans les sauts (Kraemer et al., 2001). Par compte, des résultats incohérents sont retrouvés dans la littérature pour ce qui est de l'effet PV sur les sauts. La divergence des paramètres de vibrations peut être à la source de ce problème car non seulement les paramètres de vibration sont très différents d'une étude à l'autre, mais les caractéristiques des sujets aussi sont également très variables. Une étude a pu démontrer que les sujets qui ont complété un entraînement en vibration de haute fréquence / haute amplitude (50 Hz, 4mm) ont amélioré leur performances de sauts alors qu'aucunes différences n'a été trouvé pour le groupe de basse fréquence / basse amplitude (30 Hz, 2mm) (Petit et al., 2010). L'intensité de l'exercice en vibration dans la présente étude était probablement trop basse pour nos sujets féminins en surpoids pour avoir un effet sur les sauts. De plus, nos sujets étaient peut-être en plus actifs que nous l'avions imaginé car l'inactivité n'était pas un critère d'inclusion. Afin de bien comprendre les effets de l'entraînement PV, un certain ordre doit être mit dans ces études pour trouver les paramètres optimaux en fonction du type de sujet mais aussi en fonction des composantes qu'on veut améliorer que ce soit la force, la puissance ou la fatigue musculaire.

4.3 Entraînement PV et puissance

L’impact de l’entraînement PV sur la puissance des membres inférieurs a été mesuré par le test Wingate. Les résultats de cette étude nous indiquent que la modalité d'entraînement utilisée, avec ou sans plateforme de vibration, n'ont eu aucun effet sur la puissance des membres inférieurs. Dans la littérature, l’entraînement de force traditionnel de 6 semaines chez les femmes en surpoids augmente normalement la puissance des membres inférieurs tel que mesurer par le test Wingate (Kraemer et al., 1997). Plusieurs recherches démontrent aussi que l’entraînement PV peut efficacement augmenter la puissance des membres inférieurs (Adams et al., 2009; Di Giminiani et al., 2009; Rees et al., 2008). Il a été suggéré qu’une meilleure réponse à l’entraînement est obtenue lorsque les paramètres de vibration sont individualisés en fonction de la réponse musculaire (RMS) à la vibration et non présélectionnés (Di Giminiani et al., 2009). Dans la présente étude, nous avons présélectionné les paramètres de la vibration en se basant sur ceux dans la littérature. Nous avons opté pour un entraînement en vibration à plus faible intensité et plus conservateur pour éviter le décrochage de nos sujets. Il serait recommandé d’individualiser le protocole de vibration dans des études subséquentes en prenant en considération la réponse d’EMG aux paramètres spécifiques de vibrations.

4.4 Entraînement PV et force

Nous avons observé une réduction inattendue de la force dynamique durant la phase d’extension en ecc120°/s et durant la phase de flexion en con120°/s et con180°/s pour le groupe VIB. Comme il n’y a pas eu de changements de masse maigre, ces résultats portent à croire que la réduction de la force n’est pas due à des changements morphologiques mais plutôt centraux. Aucun changement n’a été noté pour le groupe contrôle. Ceci porte à croire que les paramètres de vibration employés ont été néfastes pour la force musculaire chez les femmes en surpoids comparé au même entraînement sans vibration. Certaines études ont démontré que l'entraînement PV chez les adultes en santé (hommes et femmes) augmente la force musculaire des membres inférieurs en améliorant entre autre la co-contraction des muscles synergistes et la synchronisation des unités motrices (Abercromby et al., 2007a; C. Bosco et al., 1998). Une étude a pu démontrer que l'entraînement en vibration avec des paramètres de basse fréquence/basse amplitude n'ont pas toujours des effets sur la force musculaire alors que les paramètres de haute fréquence/haute amplitude produisent des effets favorables sur la force et la puissance (Marin & Rhea, 2010). Une autre étude a même démontré que l'entraînement PV avec basse fréquence/basse amplitude ne provoque aucun changement et peut même diminuer la force musculaire des muscles de la jambe (Colson et al., 2009; Jordan et al., 2010). La présente étude a démontré que l'entraînement PV chez les jeunes femmes en surpoids diminue la force musculaire dynamique pendant les contractions à grandes vitesses et n'a aucun effet sur les contractions à basses vitesses ou en isométrie. Les paramètres de vibration utilisés dans cette étude n'étaient pas favorables pour une amélioration de la force musculaire mais ont en effet provoqué une diminution de la force musculaire.

4.5 Entraînement PV, fatigue et efficacité neuromusculaire

À notre connaissance, cette recherche est la première à enquêter l'effet de l'entraînement en vibration sur la fatigue musculaire chez les femmes en surpoids. Le taux de fatigue du moment qui était représenté par les pentes de régression des moments à diminuer pour les extenseurs du genou que pour le groupe control. Le taux a aussi diminué pour les fléchisseurs chez les deux groupes, or, le groupe CON a diminué significativement plus que le groupe VIB. Cette étude a démontré que l'entraînement PV a causé que le groupe VIB soit plus résistant à la fatigue que le groupe CON post-entraînement. Il a été suggéré que les hommes sont moins résistants à la fatigue que les femmes et les adultes moins que les enfants car le taux de fatigue est associé avec la force maximale et la masse maigre. Comme il n'y a eu aucune augmentation de masse maigre ni de force musculaire maximale, il est attendu qu'il n'y ait aucune augmentation pour le taux de fatigue chez les femmes en surpoids.

Les changements de l'efficacité neuromusculaire sont expliqués par des modifications au niveau périphérique et/ou au niveau central au cours de la fatigue. Aucune altération en efficacité neuromusculaire n'a été trouvée dans le groupe VIB au cours de cette recherche. Normalement, lorsqu'il y a une amélioration de l'efficacité neuromusculaire, une augmentation de la force musculaire suit mais comme aucune n'a été trouvée, ce n'est pas surprenant que l'efficacité neuromusculaire n'ait pas changée. Ces résultats nous démontrent que l'entraînement PV à plus faible intensité n'apporte aucun changement de périphérie ni central car il n'y a eu aucun changement d'efficacité neuromusculaire ni de force musculaire.

La fatigue est non seulement l'épuisement lors d'un exercice mais est aussi l'épuisement qu'on ressent quotidiennement. Des questionnaires de perception de fatigue (FSS, MFI et SHARP) ont été utilisés afin de quantifier la fatigue en utilisant une approche multidimensionnelle. Il est clair que l'entraînement PV de cette étude ainsi que l'entraînement sans vibration n'a causé aucuns changements de fatigue, des composantes sensibles aux modifications physiologiques et sensibles à l'activité physique telles que l'efficacité neuromusculaire, la force, la puissance, les sauts, les mesures anthropométriques et le métabolisme de base chez les jeunes femmes adultes en surpoids.

4.6 Les effets néfastes de la vibration

Il est bien documenté que l'exposition longue et fréquente aux vibrations peut être dangereuse pour la santé (Plewa et al., 2012). Plusieurs travailleurs tel que les conducteurs de camions, ceux travaillant dans le secteur minier et de la construction sont souvent exposés aux vibrations. Des problèmes vasculaires, sensorielle ou musculo-squelettiques tels que le phénomène de Raynaud, une réduction de la sensation dans les doigts ou une diminution de la force de préhension peuvent être causés par cette exposition (Bovenzi, M., 2005). Il faut garder en tête que ces fréquences sont beaucoup plus basses et dangereuses que celles utilisées avec les plateformes à vibration. Par contre les effets de ces plateformes sur le corps (négatifs et positifs) ne sont pas encore bien connus.

4.7 Limites et conclusion

Une des limites de cette étude porte sur les caractéristiques des vibrations. Le manque d'individualisation des vibrations est peut-être la raison pour laquelle l'entraînement à vibration n'a entrainé aucun effet. Une étude chez les jeunes adultes actifs a démontré que l'entraînement à vibration individualisé apporte plus de changements neuromusculaires qu'un entraînement à vibration avec des fréquences et amplitudes présélectionnées (Di Giminiani et al., 2009).

Les femmes qui ont pris part à cette étude faisaient du surpoids caractérisé par le pourcentage de masse grasse, plusieurs d'entre elles effectuaient régulièrement de l'exercice physique. Il est possible que le manque d'effet de l'entraînement à vibration dans cette étude soit dû au fait que la fréquence et l'amplitude ne sont pas assez élevées pour provoquer un changement chez ce groupe. Ajouter une caractéristique d'inclusion qui porte sur le sédentarisme des participantes aurait peut-être changé les résultats de cette étude.

Pour ce qui est du cycle de déconditionnement, l'entraînement PV pourrait peut-être couper ce cycle, car il diminue l'index de fatigue des membres inférieurs. Une étude longitudinale pourrait mieux déterminer si l'entraînement PV a un effet à long terme sur le cycle de déconditionnement chez les femmes en surpoids.

Une dernière limite serait que le protocole d'entraînement a commencé au printemps et a fini en été. Il est connu des chercheurs que des changements saisonniers en activité physique existent surtout chez les populations de pays industrialisés. (Goran MI, 1998; Pivarnik, Reeves, & Rafferty, 2003; Weydahl, 1990). Nos résultats démontrent que la dépense énergétique de nos sujets a augmentée de 30% post-entraînement pour les 2 groupes ce qui pourrait être en lien avec le climat. Ce type d'entraînement pourrait être bénéfique plutôt pendant la saison hivernale.

Pour conclure, cette étude nous a démontré que l'entraînement PV chez les jeunes femmes adultes en surpoids a pu améliorer l'index de fatigue des membres inférieurs mesuré par le Wingate. Par contre, cet entraînement n'a aucun effet sur les sauts, la composition corporelle, le métabolisme de base, la force, la puissance et la fatigue des membres inférieurs ainsi que la perception de fatigue chez les jeunes femmes adultes en surpoids. Même si cet entraînement n'a eu aucun effet supplémentaire comparé au groupe control, il faut souligner que le simple fait de faire de l'exercice c'est un début. Si l'entraînement PV motive des gens à s'entrainer, cela est déjà mieux que d'être sédentaire.

Les prochaines études pourraient s'intéressées à l'efficacité de l'entraînement PV avec des paramètres individualisés chez les femmes sédentaires et en surpoids.

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Appendix A

Nutritional journals summary

	VIB group (pre)	VIB group (post)	CON group (pre)	CON group (post)
Kcal/day	1919.8 ± 540.07	1922.5 ± 480.48	1915.8 ± 351.07	1943.9 ± 263.13

Appendix B

Fatigue perception questionnaires

FSS (Fatigue Severity Scale, for total fatigue)

A low value (e.g., 1) indicates strong disagreement with the statement, whereas a high value (e.g., 7) indicates strong agreement.

During the past week, I have found that:

1. My motivation is lower when I am fatigued.
1 2 3 4 5 6 7

2. Exercise brings on my fatigue.
1 2 3 4 5 6 7

3. I am easily fatigued.
1 2 3 4 5 6 7

4. Fatigue interferes with my physical functioning.
1 2 3 4 5 6 7

5. Fatigue causes frequent problems for me.
1 2 3 4 5 6 7

6. My fatigue prevents sustained physical functioning.
1 2 3 4 5 6 7

7. Fatigue interferes with carrying out certain duties and responsibilities.
1 2 3 4 5 6 7

8. Fatigue is among my three most disabling symptoms.
1 2 3 4 5 6 7

9. Fatigue interferes with my work, family, or social life.
1 2 3 4 5 6 7

MFI® MULTIDIMENSIONAL FATIGUE INVENTORY
® E. Smets, B.Garssen, B. Bonke.

Instructions:

By means of the following statements we would like to get an idea of how you have been feeling **lately**.
There is, for example, the statement:
"I FEEL RELAXED"
If you think that this is **entirely true**, that indeed you have been feeling relaxed lately, please, place an **X** in the extreme left box; like this:
yes, that is true ☒1 ❑2 ❑3 ❑4 ❑5 no, that is not true
The more you **disagree** with the statement, the more you can place an **X** in the direction of "no, that is not true". Please do not miss out a statement and place only one **X** in a box for each statement.

1	I feel fit.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
2	Physically, I feel only able to do a little.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
3	I feel very active.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
4	I feel like doing all sorts of nice things.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
5	I feel tired.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
6	I think I do a lot in a day.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
7	When I am doing something, I can keep my thoughts on it.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
8	Physically I can take on a lot.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
9	I dread having to do things.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**

10	I think I do very little in a day.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
11	I can concentrate well.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
12	I am rested.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
13	It takes a lot of effort to concentrate on things.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
14	Physically I feel I am in a bad condition.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
15	I have a lot of plans.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
16	I tire easily.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
17	I get little done.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
18	I don't feel like doing anything.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
19	My thoughts easily wander.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**
20	Physically I feel I am in an excellent condition.	**yes, that is true**	❑ **1**	❑ **2**	❑ **3**	❑ **4**	❑ **5**	**no, that is not true**

Thank you very much for your cooperation

SHARP

These questions are about how things have been going for you lately.

Please answer "yes" or "no" to the following:

During the past month have you felt...

1.	In high spirits?	YES	NO
2.	Particularly content with your life?	YES	NO
3.	Depressed or very unhappy?	YES	NO
4.	Flustered as you didn't know what was expected of you?	YES	NO
5.	Bitter about the way your life has turned out?	YES	NO
6.	Generally satisfied with how your life has turned out?	YES	NO

The next questions have to do with general life experiences.

7.	I am just as happy as when I was younger.	YES	NO
8.	As I look back on my life, I am fairly well satisfied.	YES	NO
9.	Things are getting worse as I get older.	YES	NO
10.	Little things bother me more this year.	YES	NO
11.	Life is hard for me most of the time.	YES	NO
12.	I am satisfied with my life today.	YES	NO

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